

# Guide to the Geology of the Hamilton–Warsaw Area, Hancock County, Illinois

Wayne T. Frankie and Russel J. Jacobson  
Illinois State Geological Survey



Field Trip Guidebook 1998A  
April 18, 1998

Department of Natural Resources  
ILLINOIS STATE GEOLOGICAL SURVEY



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**Cover photo** Geode from Hancock County (photo by Joel Dexter).

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**Geological Science Field Trips** The Geoscience Education and Outreach Unit of the Illinois State Geological Survey (ISGS) conducts four free tours each year to acquaint the public with the rocks, mineral resources, and landscapes of various regions of the state and the geological processes that have led to their origin. Each trip is an all-day excursion through one or more Illinois counties. Frequent stops are made to explore interesting phenomena, explain the processes that shape our environment, discuss principles of earth science, and collect rocks and fossils. People of all ages and interests are welcome. The trips are especially helpful to teachers who prepare earth science units. Grade school students are welcome, but each must be accompanied by a parent or guardian. High school science classes should be supervised by at least one adult for each ten students.

A list of guidebooks of earlier field trips for planning class tours and private outings may be obtained by contacting the Geoscience Education and Outreach Unit, Illinois State Geological Survey, Natural Resources Building, 615 East Peabody Drive, Champaign, IL 61820-6964. Telephone: (217) 244-2427 or 333-4747.

Four USGS 7.5-Minute Quadrangle maps (Hamilton, Keokuk, Sutter, and Warsaw) provide coverage for this field trip area.

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Era	Period or System and Thickness	Epoch	Age (years ago)	General Types of Rocks	
CENOZOIC "Recent Life"	Quaternary 0-500'	Holocene	10,000	Recent—alluvium in river valleys	
		Pleistocene Glacial Age		Glacial till, glacial outwash, gravel, sand, silt, lake deposits of clay and silt, loess and sand dunes; covers nearly all of state except northwest corner and southern tip	
	Tertiary 0-500'	Pliocene	1.6 m. 5.3 m.	Chert gravel, present in northern, southern, and western Illinois	
		Eocene	36.6 m.	Mainly micaceous sand with some silt and clay; present only in southern Illinois	
		Paleocene	57.8 m. 66.4 m.	Mainly clay, little sand; present only in southern Illinois	
MESOZOIC "Middle Life"	Cretaceous 0-300'		144 m. 286 m.	Mainly sand, some thin beds of clay and, locally, gravel	
PALEOZOIC "Ancient Life"	Pennsylvanian 0-3,000' ("Coal Measures")			Largely shale and sandstone with beds of coal, limestone, and clay	
	Mississippian 0-3,500'		320 m.	Black and gray shale at base; middle zone of thick limestone that grades to siltstone, chert, and shale; upper zone of interbedded sandstone, shale, and limestone	
	Devonian 0-1,500'		360 m.	Thick limestone, minor sandstones and shales; largely chert and cherty limestone in southern Illinois; black shale at top	
	Silurian 0-1,000'		408 m.	Principally dolomite and limestone	
			438 m.	Largely dolomite and limestone but contains sandstone, shale, and siltstone formations	
	Ordovician 500-2,000'		505 m.		
	Cambrian 1,500-3,000'		570 m.	Chiefly sandstones with some dolomite and shale; exposed only in small areas in north-central Illinois	
	Precambrian			Igneous and metamorphic rocks; known in Illinois only from deep wells	

Generalized geologic column showing succession of rocks in Illinois.

## HAMILTON-WARSAW AREA

The Hamilton-Warsaw area geological science field trip will acquaint you with the *geology*<sup>\*</sup>, landscape, and mineral resources for part of Hancock County, Illinois. Hamilton is located in west-central Illinois along the Mississippi River. It is approximately 260 miles southwest of Chicago, 110 miles west of Springfield, 165 miles north of East St. Louis, and 315 miles northwest of Cairo. The region around Keokuk, Iowa, and Hamilton and Warsaw, Illinois, is probably the world's most famous geode-collecting area. Geodes exhibiting considerable beauty and variety of form and mineral composition are abundant in the lower part of the Warsaw Formation.

### GEOLOGIC FRAMEWORK

**Precambrian Era** Through several billion years of geologic time, Hancock County and surrounding areas have undergone many changes (see the rock succession column, facing page). The oldest rocks beneath the field trip area belong to the ancient Precambrian *basement complex*. We know relatively little about these rocks from direct observations because they are not exposed at the surface anywhere in Illinois. Only about 35 drill holes have reached deep enough for geologists to collect samples from Precambrian rocks of Illinois. From these samples, however, we know that these ancient rocks consist mostly of granitic and rhyolitic *igneous*, and possibly *metamorphic*, crystalline rocks formed about 1.5 to 1.0 billion years ago. From about 1 billion to about 0.6 billion years ago, these Precambrian rocks were exposed at the surface. During this long period, the rocks were deeply weathered and eroded, and formed a barren landscape that was probably quite similar to the topography of the present Missouri Ozarks. We have no rock record in Illinois for the long interval of *weathering* and erosion that lasted from the time the Precambrian rocks were formed until the first Cambrian-age *sediments* accumulated, but that interval is almost as long as the time from the beginning of the Cambrian Period to the present.

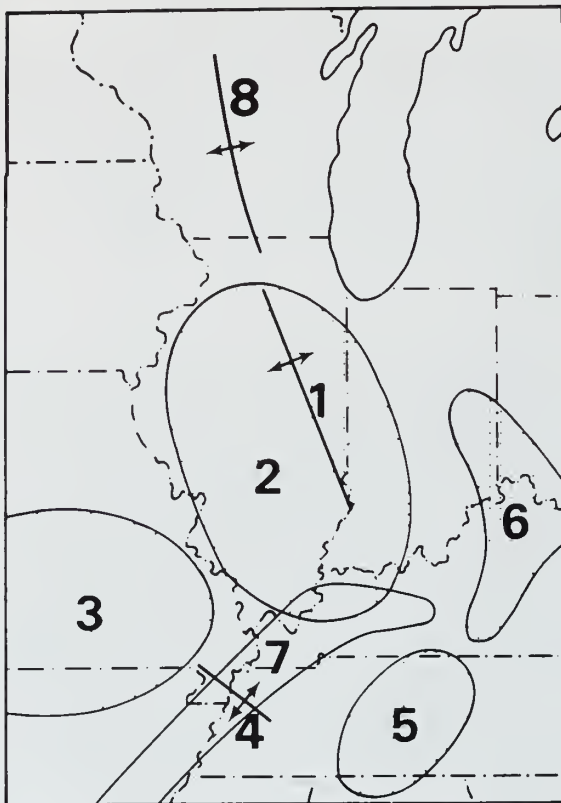
Because geologists cannot see the Precambrian basement rocks in Illinois except as cuttings and cores from boreholes, they must use other various techniques, such as measurements of Earth's gravitational and magnetic fields, and seismic exploration, to map out the regional characteristics of the basement complex. The evidence collected from these various techniques indicates that in southernmost Illinois, near what is now the historic Kentucky-Illinois Fluorspar Mining District, *rift* valleys like those in east Africa formed as movement of crustal plates (plate *tectonics*) began to rip apart the Precambrian North American continent. These rift valleys in the midcontinent region are referred to as the Rough Creek Graben and the Reelfoot Rift (fig. 1).

**Paleozoic Era** After the beginning of the Paleozoic Era, about 520 million years ago in the late Cambrian Period, the rifting stopped and the hilly Precambrian landscape began to sink slowly on a broad regional scale, allowing the invasion of a shallow sea from the south and southwest. During the 280 million years of the Paleozoic Era, the area that is now called the Illinois Basin continued to accumulate sediments that were deposited in the shallow seas that repeatedly covered this subsiding basin. The region continued to sink until at least 15,000 feet of sedimentary strata were deposited. At various times during this era, the seas withdrew and deposits were weathered and eroded. As a result, there are some gaps in the sedimentary record in Illinois.

In the field trip area, *bedrock* strata range in age from more than 520 million years (the Cambrian *Period*) to less than 360 million years old (the Mississippian Period). Figure 2 shows the succession

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<sup>\*</sup> Words in italics are defined in the glossary at the back of the guidebook. Also please note: although all present localities have only recently appeared within the geologic time frame, we use the present names of places and geologic features because they provide clear reference points for describing the ancient landscape.



**Figure 1** Location of some of the major structures in the Illinois region. (1) La Salle Anticlinorium, (2) Illinois Basin, (3) Ozark Dome, (4) Pascola Arch, (5) Nashville Dome, (6) Cincinnati Arch, (7) Rough Creek Graben-Reelfoot Rift, and (8) Wisconsin Arch.

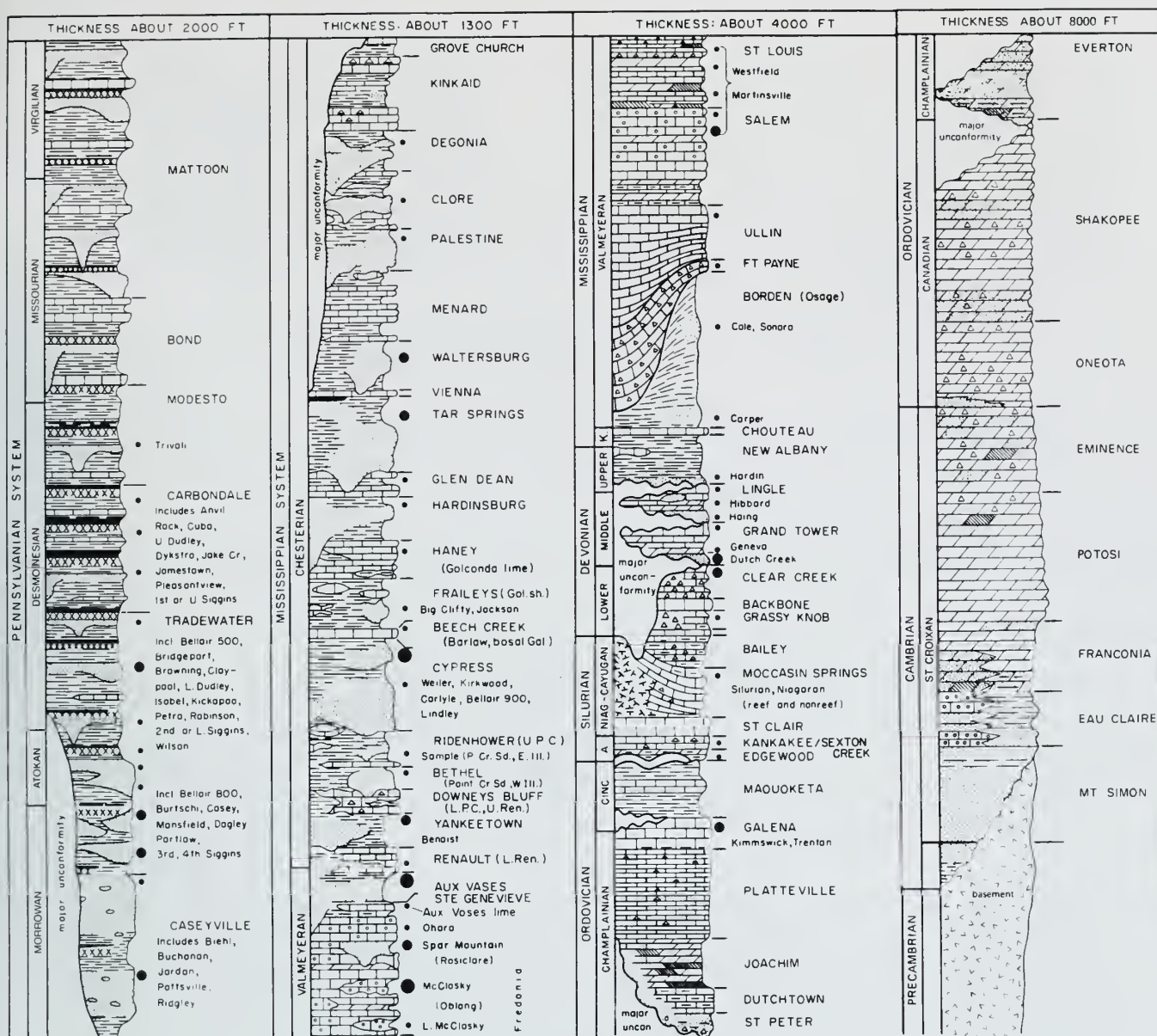
of rock strata a drill bit would penetrate in this area if the rock record were complete and all the *formations* were present.

The elevation of the top of the Precambrian basement rocks within the field trip area ranges from 2,400 feet below sea level in western Hancock County to 2,700 feet below sea level in eastern Hancock County. The thickness of the Paleozoic sedimentary strata deposited on top of the Precambrian basement ranges from about 2,900 feet in western Hancock County to about 3,300 feet in eastern Hancock County.

### **STRUCTURAL AND DEPOSITIONAL HISTORY**

As noted previously, the Rough Creek Graben and the Reelfoot Rift (figs. 1 and 3) were formed by tectonic activity that began in the latter part of the Precambrian Era and continued until the Late Cambrian. Toward the end of the Cambrian, rifting ended and the whole region began to subside, allowing shallow seas to cover the land.

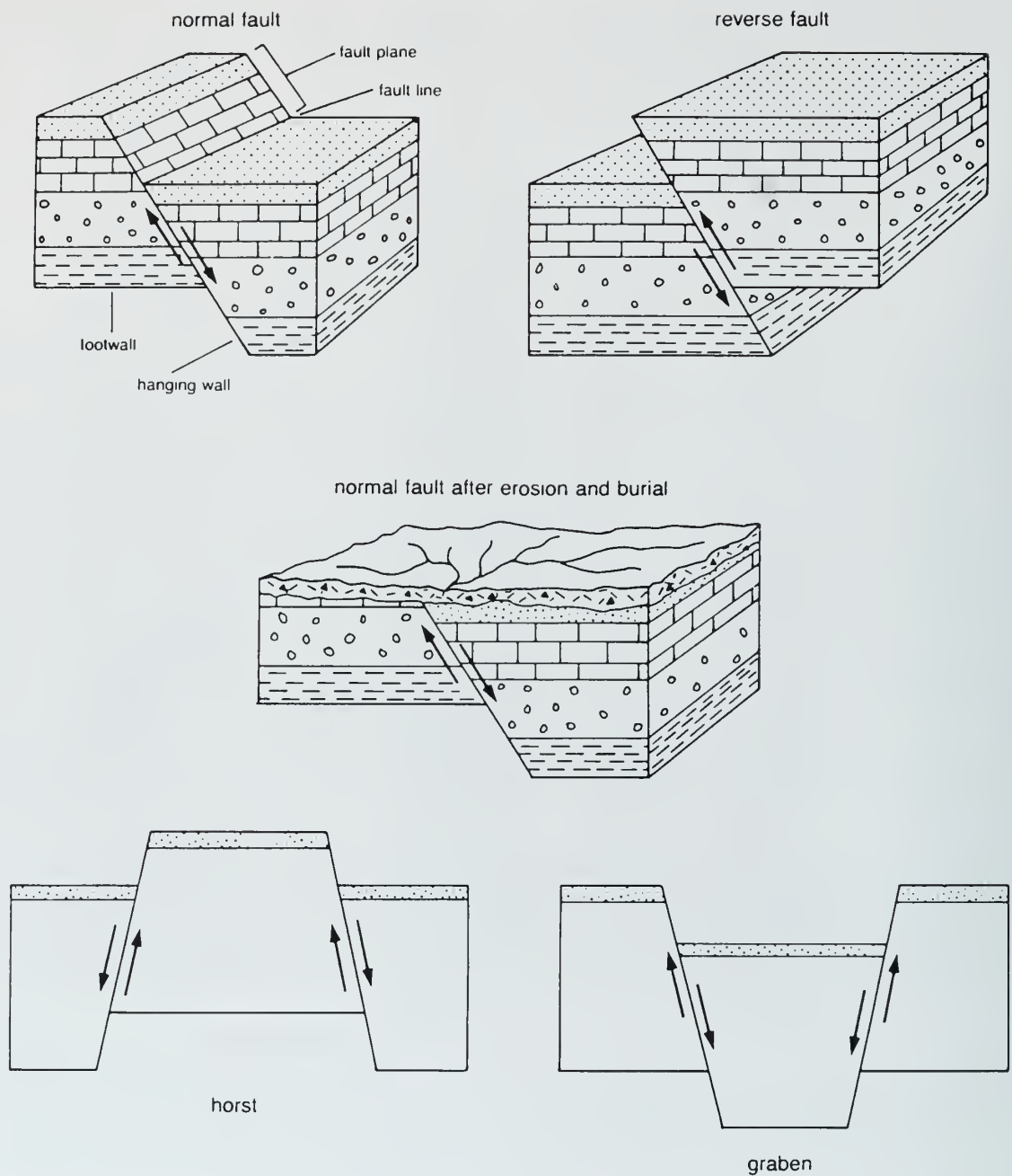
**Paleozoic and Mesozoic Eras** From the Late Cambrian to the end of the Paleozoic Era, sediments continued to accumulate in the shallow seas that repeatedly covered Illinois and adjacent states. These inland seas connected with the open ocean to the south during much of the Paleozoic, and the area that is now southern Illinois was like an embayment. The southern part of Illinois and adjacent parts of Indiana and Kentucky sank more rapidly than the areas to the north, allowing a greater thickness of sediment to accumulate. During the Paleozoic and Mesozoic, the Earth's thin crust was periodically flexed and warped in places as stresses built up in response to the tectonic forces associated with the collision of continental and oceanic plates and mountain building. These movements



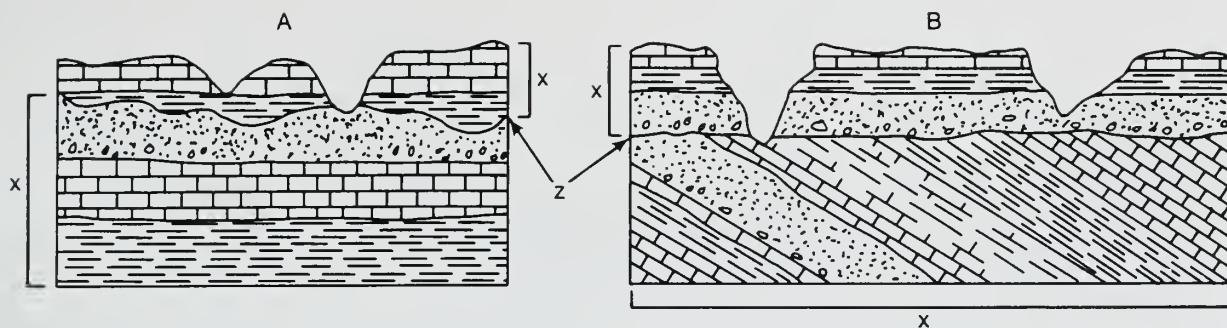
**Figure 2** Generalized stratigraphic column of the Paleozoic rocks in the field trip area. Black dots indicate oil and gas pay zones. Unconformities are indicated by wavy lines.

caused repeated invasions and withdrawals of the seas across the region. The former sea floors were thus periodically exposed to erosion, which removed some sediments from the rock record.

Many of the sedimentary units, called *formations*, have *conformable* contacts—that is, no significant interruption in deposition occurred as one formation was succeeded by another (figs. 2 and 4). In some instances, even though the composition and appearance of the rocks change significantly at the contact between two formations, the *fossils* in the rocks and the relationships between the rocks at the contact indicate that deposition was virtually continuous. In contrast however, in some places, the top of the lower formation was at least partially eroded before deposition of the next formation began. In these instances, fossils and/or other evidence within or at the boundary between the two formations indicate that there is a significant age difference between the lower unit and the overlying



**Figure 3** Diagrammatic illustrations of fault types that may be present in the field trip area (arrows indicate relative directions of movement on each side of the fault).



**Figure 4** Schematic drawings of (A) a disconformity and (B) an angular unconformity (x represents the conformable rock sequence and z is the plane of unconformity).

unit. This type of contact is called an *unconformity* (fig. 4). If the *beds* above and below an unconformity are parallel, the unconformity is called a *disconformity*. However, if the lower beds were tilted and eroded prior to deposition of overlying beds, the contact is called an angular unconformity.

Unconformities occur throughout the Paleozoic rock record and are shown in the generalized stratigraphic column in figure 2 as wavy lines. Each unconformity represents an extended interval of time for which there is no rock record.

Near the close of the Mississippian Period, gentle arching of the rocks in eastern Illinois initiated the development of the La Salle Anticlinorium (figs. 1 and 5). This is a complex structure having smaller structures such as domes, *anticlines*, and *synclines* superimposed on the broad upwarp of the anticlinorium. Further gradual arching continued through the Pennsylvanian Period. Because the youngest Pennsylvanian strata are absent from the area of the anticlinorium (either because they were not deposited or because they were eroded), we cannot determine just when folding ceased—perhaps by the end of the Pennsylvanian or during the Permian Period a little later, near the close of the Paleozoic Era.

**Mesozoic Era** During the Mesozoic Era, the rise of the Pascola Arch (fig. 1) in southeastern Missouri and western Tennessee produced a structural barrier that helped form the current shape of the Illinois Basin by closing off the embayment and separating it from the open sea to the south. The Illinois Basin is a broad, subsided region covering much of Illinois, southwestern Indiana, and western Kentucky (fig. 1). Development of the Pascola Arch, in conjunction with the earlier sinking of the deeper portion of the basin north of the Pascola Arch in southern Illinois, gave the basin its present asymmetrical, spoon-shaped configuration (fig. 6). The geologic map (fig. 7) shows the distribution of the rock *systems* of the various geologic time periods as they would appear if all the glacial, wind-blown, and surface materials were removed.

The Hamilton-Warsaw field trip area is located along the eastern flank of the Mississippi River Arch (fig. 5). This arch forms a structural divide between the Illinois and Forest City Basins. The Mississippi River Arch trends slightly northeast–southwest along the Mississippi River in southeastern Iowa, northwestern Illinois, and northeastern Missouri. The present arch developed after the Morrowan (early Pennsylvanian) Epoch. An earlier arch existed in the same general area and was beveled by the sub-Kaskaskia (pre-middle Devonian) unconformity (W.J. Nelson 1995). Locally, the Warsaw Dome is a small structure located about 3 miles northeast of Warsaw near the crest of the larger Mississippi River Arch in Section 1, T4N, R9W. The Warsaw Dome is centered about 0.5 mile south of the bridge that crosses Crystal Glen Creek on the Warsaw road between Hamilton and Warsaw. The dome is about 5 miles in diameter and covers approximately 50 square miles. It is an elongated

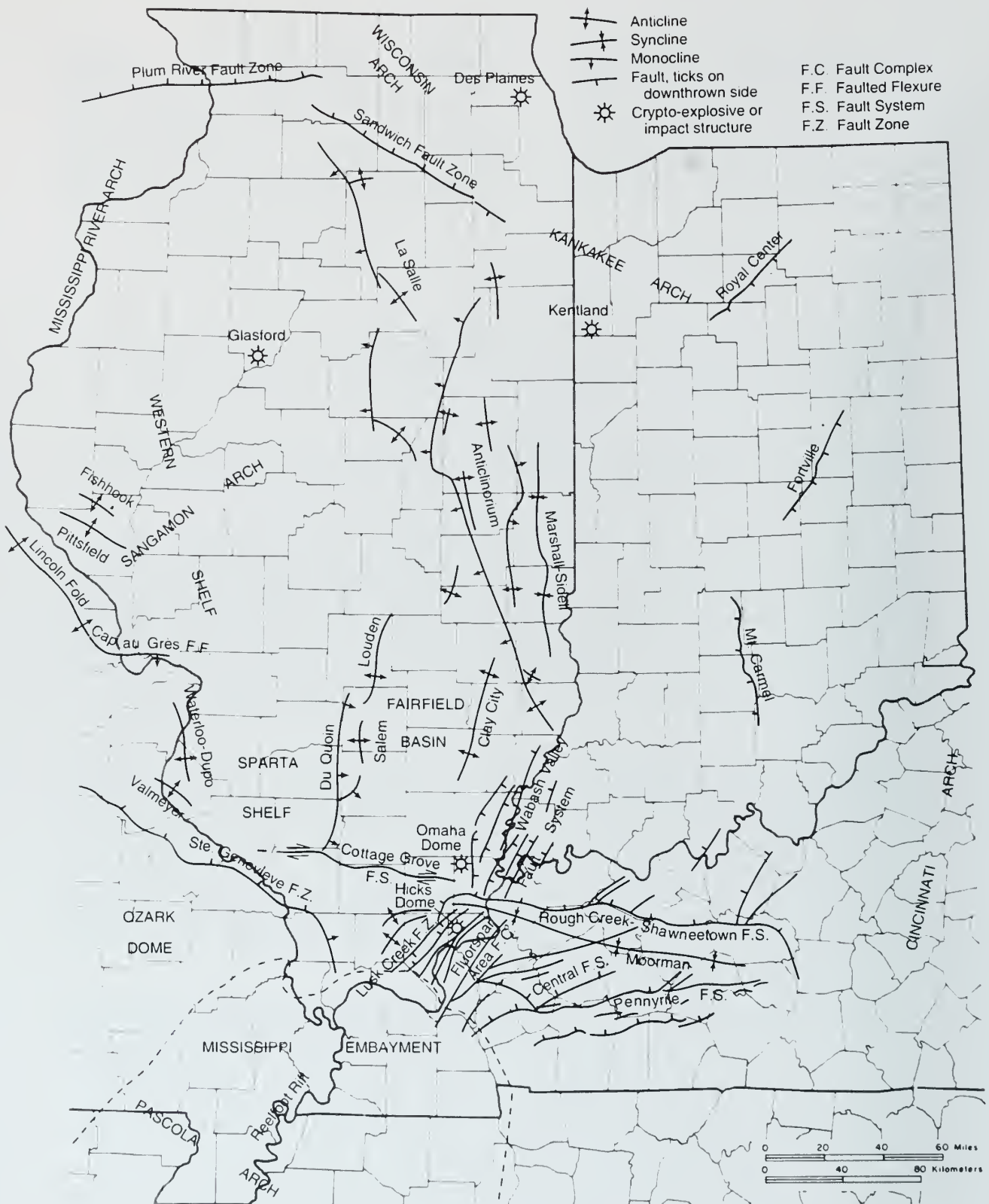
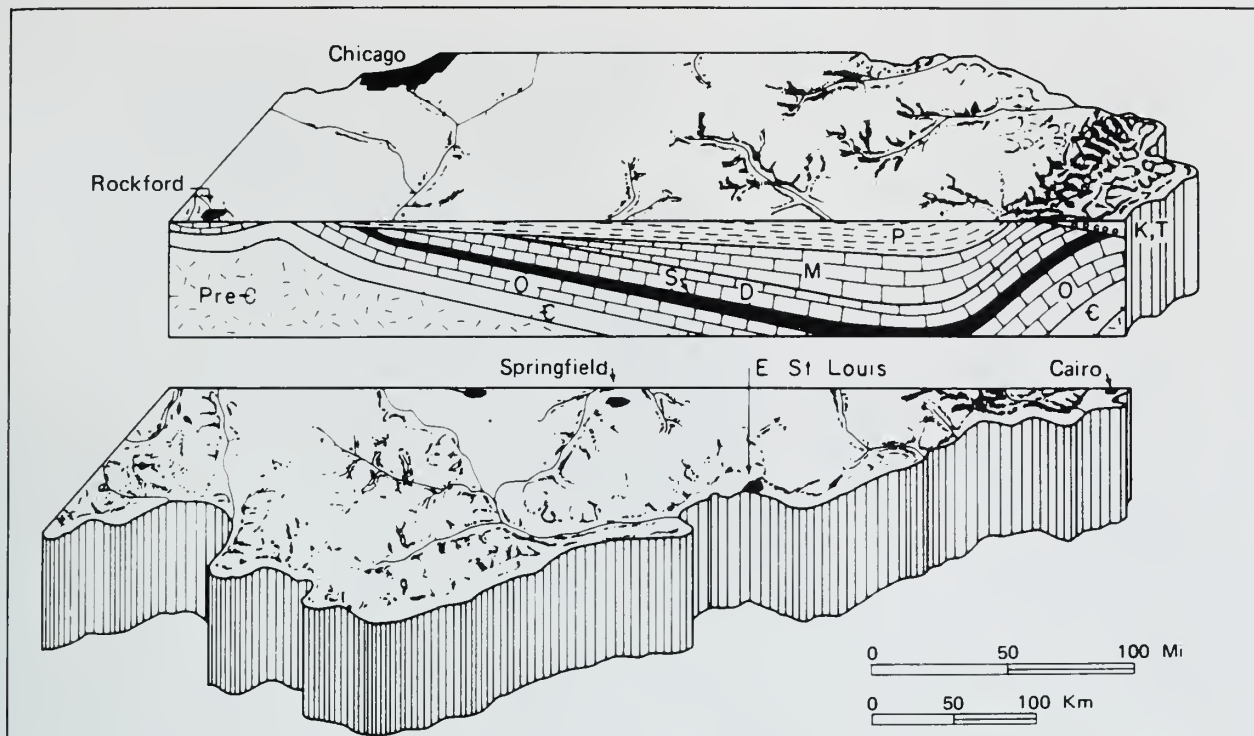


Figure 5 Structural features of Illinois (modified from Buschbach and Kolata 1991).

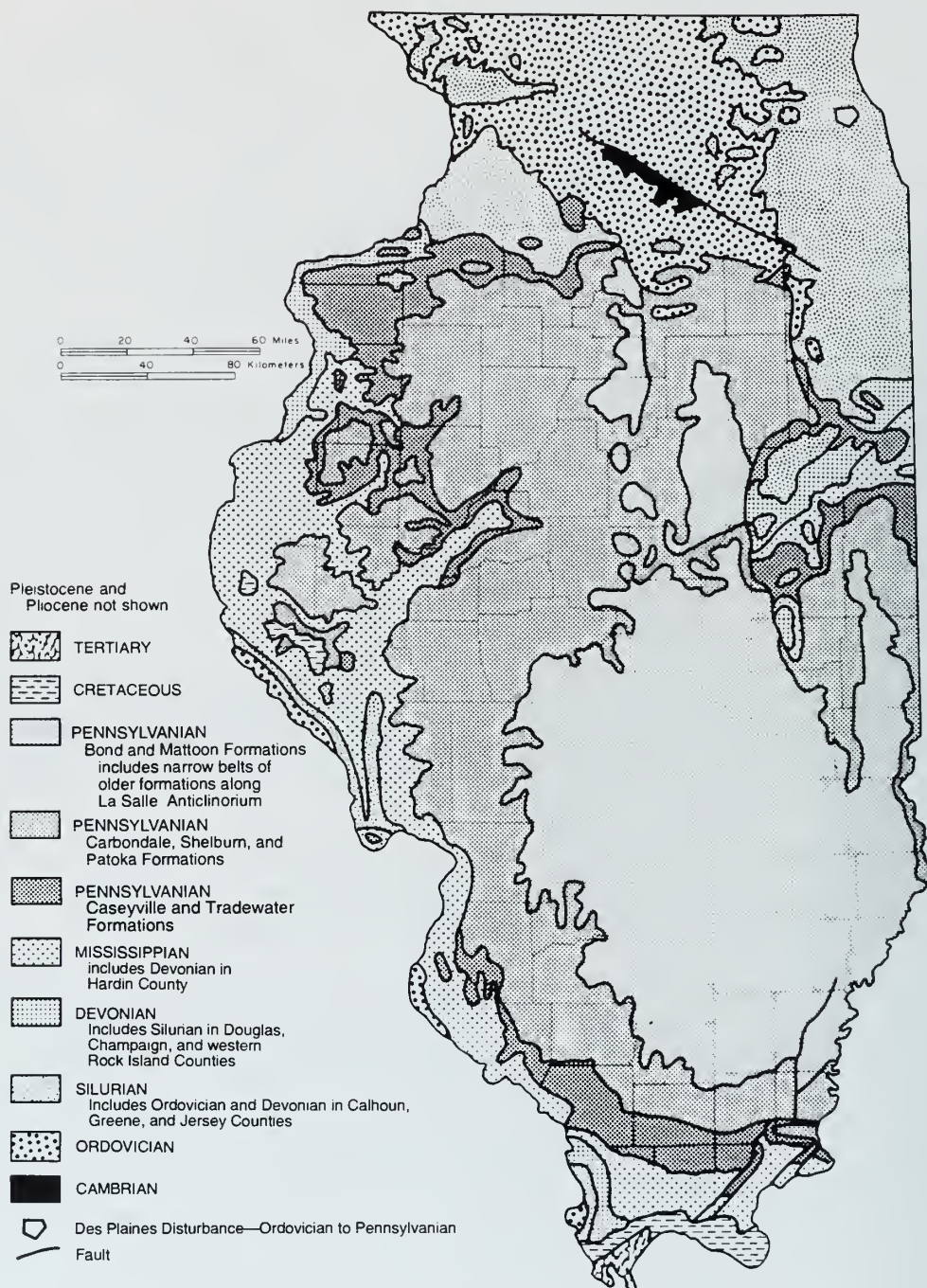


**Figure 6** Stylized north-south cross section shows the structure of the Illinois Basin. To show detail, the thickness of the sedimentary rocks has been greatly exaggerated and younger, unconsolidated surface deposits have been eliminated. The oldest rocks are Precambrian (Pre-C) granites. They form a depression filled with layers of sedimentary rocks of various ages: Cambrian (C), Ordovician (O), Silurian (S), Devonian (D), Mississippian (M), Pennsylvanian (P), Cretaceous (K), and Tertiary (T). Scale is approximate.

dome trending northeast-southwest and has a closure (distance between a structure's highest point and its lowest closed structural contour) of about 30 feet. Shows of oil have been reported from the Devonian Hoing sand at a depth of about 600 feet.

Younger rocks of the latest Pennsylvanian and perhaps the Permian (the youngest rock systems of the Paleozoic) may have at one time covered the area of Hancock County. It is possible that Mesozoic and Cenozoic rocks (see the generalized geologic column) could also have been present here. Chert gravels of uncertain age (they maybe Late Cretaceous or Late Tertiary) have been mapped in Adams and Pike Counties. Indirect evidence, based on the stage of development (rank) of coal deposits and the generation and maturation of petroleum from source rocks (Damberger 1971), indicates that perhaps as much as 1.5 miles of latest Pennsylvanian and younger rocks once covered southern Illinois. During the more than 240 million years since the end of the Paleozoic Era (and before the onset of glaciation 1 to 2 million years ago), however, several thousands of feet of strata may have been eroded. Nearly all traces of any post-Pennsylvanian bedrock that may have been present in Illinois were removed. During this extended period of erosion, deep valleys were carved into the gently tilted bedrock formations (fig. 8). Later, the topographic relief was reduced by repeated advances and melting back of continental *glaciers* that scoured and scraped the bedrock surface. This glacial erosion affected all the formations exposed at the bedrock surface in Illinois. The final melting of the glaciers left behind the nonlithified deposits in which our Modern Soil has developed.

**Cenozoic Era: Glacial History** A brief general history of glaciation in North America and a description of the deposits commonly left by glaciers can be found in *Pleistocene Glaciations in Illinois* at the back of this guidebook.



**Figure 7** Bedrock geology beneath surficial deposits in Illinois.



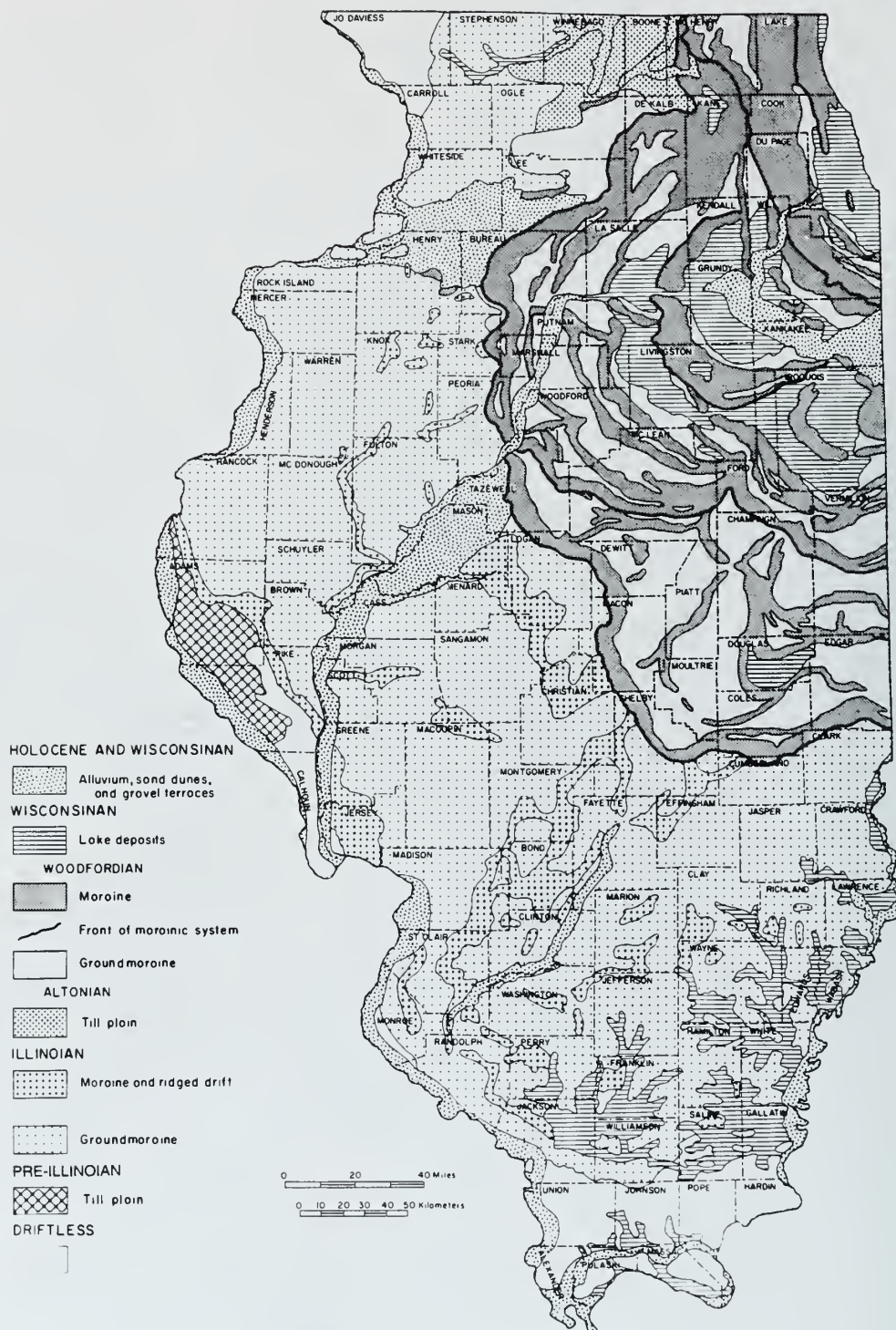


Figure 9 Generalized map of glacial deposits in Illinois (modified from Willman and Frye 1970).

During the Pleistocene *Epoch*, beginning about 1.6 million years ago, massive sheets of ice (called continental glaciers), thousands of feet thick, flowed slowly southward from Canada. The last of these glaciers melted from northeastern Illinois about 13,500 years before the present (B.P.). During the Illinois Episode, which began around 300,000 years B.P., North American continental glaciers reached their southernmost position in the northern part of Johnson County, approximately 275 miles southwest of Warsaw. The westernmost advance of the Illinois glacier extended across most of Hancock County except for a small area in the southwestern part of the county (see fig. 9). The maximum thickness of the later Wisconsin Episode glacier was about 2,000 feet in the Lake Michigan Basin, but only about 700 feet over most of the Illinois land surface (Clark et al. 1988).

The *topography* of the bedrock surface throughout much of Illinois is largely hidden from view by glacial deposits, except along the major streams. In many areas, the glacial drift is thick enough to completely mask the underlying bedrock surface. Studies of mine shafts, water-well logs, and other drill-hole information, in addition to scattered bedrock exposures in some stream valleys and roadcuts, show that the present land surface of the glaciated areas of Illinois does not reflect the underlying bedrock surface. The present topography of Illinois is significantly different from the topography of the preglacial bedrock surface. The topography of the preglacial surface has been significantly modified by glacial erosion and is subdued by glacial deposits. Wisconsin Episode *moraines* were deposited in Illinois from approximately 25,000 to 13,800 years ago.

Although Illinoian glaciers probably built morainic ridges similar to those of the later Wisconsinan glaciers, Illinoian moraines apparently were not as numerous and have been exposed to weathering and erosion for approximately 280,000 years longer than their younger Wisconsinan counterparts. For these reasons, Illinoian glacial features generally are not as conspicuous as the younger Wisconsinan features.

Overlying the Wisconsin Episode deposits is a thin cover of deposits called the Peoria *Loess* (pronounced luss), which have now been renamed the Peoria Silt (Hansel and Johnson 1996). These sediments were deposited as windblown silts during the Wisconsin Episode from 25,000 to 12,500 years ago, and mantle the glacial drift throughout the field trip area. Within Hancock County, the loess is generally greater than 12 feet and thins from west to east. This fine grained dust, which covers most of Illinois generally exceeds 15 feet near the Mississippi and Illinois Rivers.

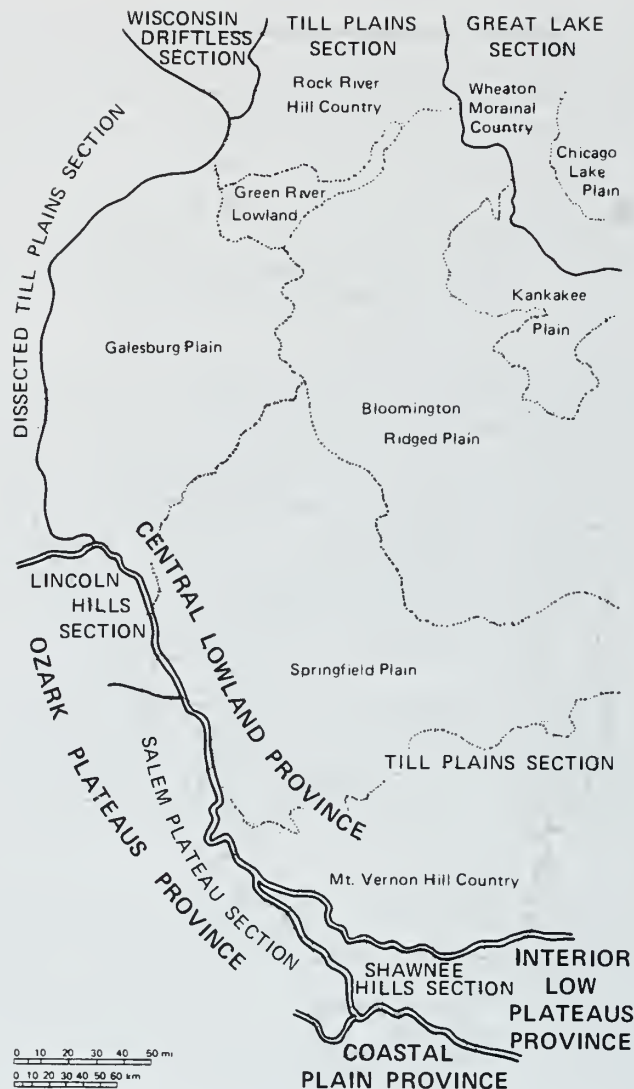
Within the field trip area, glacial drift is generally 25 to 50 feet thick but ranges in thickness from 0 feet where it has been removed by erosion and bedrock is exposed, to more than 200 feet in south central Hancock County, which corresponds to the location of the Mendon Moraine. The Mendon Moraine is discussed in the text for Stop 4.

## GEOMORPHOLOGY

**Physiography** Physiographically, the Hamilton-Warsaw area lies along the boundary between the Galesburg *Till Plains* Section (east) and the *Dissected Till Plains* Section (west); both are part of the Central Lowland Physiographic Province (fig. 10).

The rugged topography of the Dissected Till Plains Section along the bluffs bordering the Mississippi River contrasts sharply with the younger, more even, and relatively less dissected Galesburg Till Plain in the central and eastern part of Hancock County.

The Galesburg Plain in western Illinois, according to Leighton et al. (1948), includes the western segment of the Illinoian drift-sheet, a level-to-undulatory plain with a few morainic ridges that was



**Figure 10** Physiographic divisions of Illinois.

formed some 250,000 years ago and is moderately eroded. It is bounded by Meredosia Valley and the Wisconsin drift border on the northeast, by the Illinois River valley on the southeast, and by the Illinoian drift boundary on the southwest. On the northwest, the western boundary of the Galesburg Plain follows the edge of the Illinoian drift across the Mississippi River into Iowa.

The district is drained by streams that flow from a central upland westward into the Mississippi River and eastward and southward into the Illinois River. The larger valleys are steep walled, alluviated, and terraced, except for local narrowing along postglacial gorges. Much of the district is relatively high above base level, so that the minor valleys are numerous and deep.

The Illinoian drift is generally thick and is underlain by extensive pre-Illinois glacial deposits, especially along buried preglacial valleys. Most of the irregularities of the preglacial surface were filled in with older drift, so that, in contrast with the Rock River Hill Country in north central Illinois, only gross features of the bedrock topography are reflected in the present landscape.

**Drainage** Within the Hamilton-Warsaw area, drainage is westward toward the Mississippi River, which occupies a young, narrow, rock-walled gorge cut into Mississippian limestones northward from Warsaw and an older, wider, flat valley southward from Warsaw. All of the small tributaries flowing from the bluffs are deeply incised into the Mississippian limestones and the overlying Pleistocene deposits.

**Relief** The present landforms are a result of the glaciations during the Pre-Illinois, Illinois, and Wisconsin Episodes and subsequent erosion by wind and rain. The highest land surface on the field trip route is located just east of Warsaw at the junction of Main Street and the Corporate Boundary, where the surface elevation is 707 feet above mean sea level (msl). The lowest elevation is about 480 feet above msl along the Mississippi River at Warsaw. The surface relief of the field trip area, calculated as the difference between the highest and lowest surfaces, is about 227 feet. *Local relief* is most pronounced along the bluffs adjacent to the Mississippi River.

## GEOLOGY OF WEST-CENTRAL ILLINOIS\*

The outcrops, creeks, and quarries we will see on the field trip will reveal lateral and vertical variations in ancient analogs of modern depositional environments: ice-laid diamicton (tills), aeolian silts (loess), braided river deposits, delta plain and prodelta sediments, tidal channel fills, supratidal and intertidal carbonates, subtidal banks and bars of marine carbonate sands deposited above wave base, and carbonate mud banks deposited below wave base. Figure 11 shows the general stratigraphic column of deposits in western Hancock County. These formations were deposited on the western shelf of the Illinois Basin over the eastern flank of the Mississippi River Arch (fig. 5).

Mississippian and Pennsylvanian bedrock formations dip gently to the southeast toward the center of the Illinois Basin (fig. 5). Pennsylvanian formations thin and pinch out on the east flank of the Mississippi River Arch. The Mississippi River Arch was structurally and topographically high during the Mississippian and Pennsylvanian periods. During the Pleistocene Epoch, the west-central Illinois area was eroded by glaciers and meltwater streams. Deposits of Pleistocene till, loess, and outwash sands and gravels blanket most of the bedrock and form the surficial cover of the Galesburg Plain (figs. 9 and 10).

**Mississippian System (Valmeyeran Series)** The Mississippian System (Winchell 1869) was named from exposures of Carboniferous limestone in bluffs along the Mississippi River in the Illinois, Iowa, and Missouri area. In the Warsaw area, Valmeyeran-age Keokuk Limestone, Warsaw Shale, Sonora Formation, and St. Louis Limestone are well exposed. Valmeyeran beds contain a diverse fauna including numerous species of conodonts, bryozoans, trilobites, crinoids, and blastoids. See *Mississippian Rocks in Illinois* in the back of the guidebook for additional information on the Mississippian Period in Illinois.

**Keokuk Limestone** The Keokuk Limestone (Stop 6, Gray Quarry) is named after the town of Keokuk, Iowa, although Gray's Quarry in Illinois serves as a reference section of the Keokuk Limestone in the type area (Collinson 1964). The Keokuk Limestone consists mainly of thin- to thick-bedded crinoidal biosparite and minor intercalations of shale and dolomite. Bed thickness and grain size decrease toward the top of the formation. Individual beds thicken and thin quite noticeably and represent lenticular bars of carbonate sand fossil-fragments deposited above wave base. The lower 30–40 feet of the Keokuk Limestone contain beds and nodules of light gray chert that compose the Montrose Chert Member.

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\* Modified from Willard A. McCracken (1976).

# LITHOLOGY

# FORMATIONS AND MEMBERS

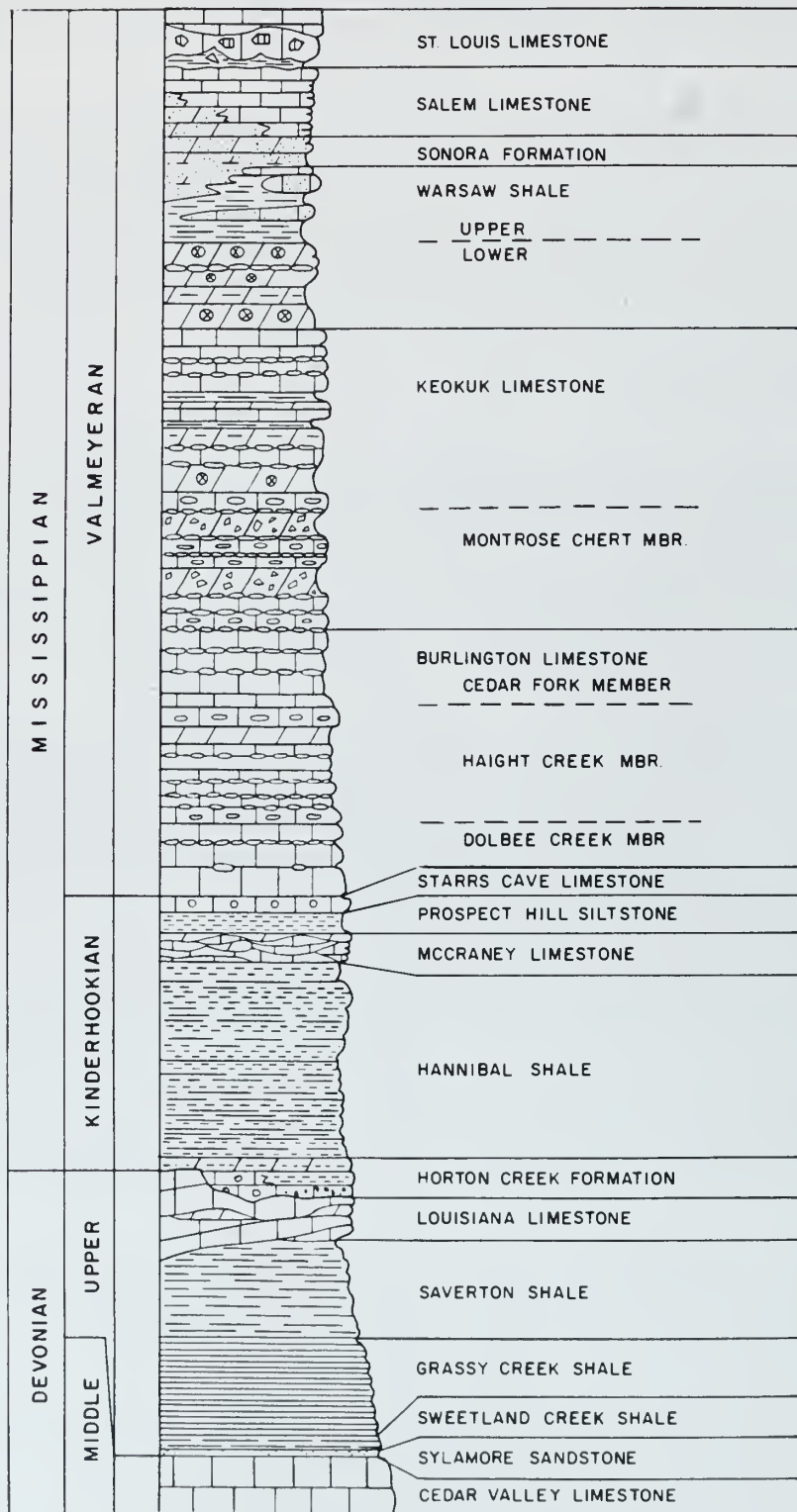


Figure 11 Generalized stratigraphic column of deposits in western Hancock County.

The Keokuk Limestone is conformably underlain by the Burlington Limestone. The Keokuk–Burlington contact is difficult to pick, and the two formations are often mapped as one unit, the Keokuk–Burlington Limestone (Wanless 1957). The upper part of the Burlington Limestone is characterized by thick beds of coarse grained crinoidal biosparite; a fish-tooth fossil zone (Spreng 1961) marks the top of the Burlington Limestone.

Numerous thin beds of shale and dolomite are interlayered with the limestone in the upper part of the Keokuk. The contact between the Keokuk Limestone and the overlying Warsaw Shale is conformable and is placed at the top of the highest calcarenite bed in the Keokuk–Warsaw sequence. The Burlington–Keokuk Limestone is extensively quarried in the area. The limestone is used for crushed stone, high-calcium lime, pulverized limestone, flux, and riprap (Lamar 1967, p. 42).

**Warsaw Shale** The type section of the Warsaw Shale will be visited at Stop 1. The Warsaw Shale consists mostly of argillaceous dolomite, dolomitic mudstone, and lesser amounts of limestone (Hayes 1964). The lower part of the Warsaw Shale is predominantly argillaceous dolomite interbedded with dolomitic mudstone. Geodes are conspicuously abundant in the dolomite beds of the lower Warsaw Shale and will be observed at Stops 1 and 6.

The upper Warsaw contains lenses of calcarenite (limestone consisting of sand-size fossil fragments) interbedded with shale. The upper Warsaw Shale is very fossiliferous and is sometimes referred to as the *Archimedes* beds (Collinson 1964). The Warsaw fauna, which has been studied in detail by Collinson (1964), includes numerous species of bryozoans, corals, brachiopods, and conodonts. The diverse fauna and fine grain size (silt and clay) of the Warsaw shales and argillaceous dolomite beds suggest that these units were deposited in open marine waters in a low-energy environment below wave base. The dolomite probably formed from early replacement of lime mud micrite. The absence of bird's-eye structures, mud cracks, and other supratidal features negate a supratidal salt flat model for the origin of the dolomite. The Burlington Limestone, Keokuk Limestone, and Warsaw Shale are all lateral equivalents of the deltaic Borden Siltstone, which was deposited at the same time in the central and eastern parts of the Illinois Basin (Willman and others 1975).

**Sonora Formation** About 1.5 feet of Sonora Formation is exposed in a roadcut on the Warsaw Highway about 0.8 miles east of Warsaw, Illinois. The Sonora is a sandy dolomite and is believed to be a lateral equivalent of the Salem Limestone. The Sonora Formation rests on the Warsaw Shale and is overlain by the St. Louis Limestone.

**St. Louis Limestone** The St. Louis Limestone is well exposed in the Gray Quarry at Stop 6. In the Colchester area, the St. Louis Limestone consists of 15–20 feet of coarse-textured limestone breccia overlain by 5–7 feet of reddish brown calcareous dolomite and limestone and 2–4 feet of light gray micrite and intraformational breccia conglomerate. The breccia is believed to be a collapse breccia that formed after the solution of gypsum and anhydrite beds.

In the subsurface of the Illinois Basin, the St. Louis Limestone contains extensive beds of gypsum and anhydrite (Cote and others, 1971). According to Willman and others (1975), limestone breccias in the outcrop areas represent the evaporites.

Field evidence supports the evaporite model of Cote and others (1971). Bird's-eye structures, algal laminations, and intraformational flat-pebble conglomerates have been observed in exotic blocks comprising the breccia. Mudcracks were also locally observed on the base of the reddish brown dolosiltstone overlying the breccia. These features suggest a supratidal environment and are in accord

with supratidal salt flat model similar to the "sabkhas" forming dolomite along the shores on the Persian Gulf today. Breccia textures within some of the large blocks in the breccia unit suggest at least two cycles of brecciation.

The St. Louis Limestone contains a restricted fauna. A rugose coral, *Lithostrotionella*, is commonly found. The *Lithostrotionella* is commonly replaced by chalcedony and is prized by collectors as a lapidary stone.

## **NATURAL RESOURCES**

**Mineral production** Of the 102 counties in Illinois, 98 reported *mineral* production during 1992, the last year for which complete records are available. The total value of all minerals extracted, processed, and manufactured in Illinois during 1995 was \$2,202,300,000, 10.9% lower than the 1994 total. Minerals extracted accounted for 87.6% of this total. Coal continued to be the leading commodity, accounting for 64% of the total, followed by industrial and construction materials at 21.4%, and oil at 14.2%. The remaining 0.4% included metals, peat, and gemstones. Illinois ranked 13th among the 31 oil-producing states in 1992 and 16th among the 50 states in total production of nonfuel minerals but continues to lead all other states in production of industrial sand and tripoli.

Hancock County ranked 86th among all Illinois counties in 1992 on the basis of the value of all minerals extracted, processed, and manufactured. Economic minerals currently mined in Hancock County include limestone quarried in the Keokuk, Burlington, St. Louis, and Salem Formations, and sand and gravel deposits from the Glasford glacial outwash. Although no coal mines are currently active in Hancock County, cumulative production totals 771,281 tons. Coal has been mined from the lower Pennsylvanian Tradewater Formation in a small area along the eastern county boundary. Limited oil production was reported in 1991 and 1992 (156 and 277 barrels respectively).

**Groundwater** Groundwater is a mineral resource frequently overlooked in assessments of an area's natural resource potential. The availability of this mineral resource is essential for orderly economic and community development. More than 35% of the state's 11.5 million citizens and 97% of those who live in rural areas depend on groundwater for their water supply. Groundwater is derived from underground formations called *aquifers*. The water-yielding capacity of an aquifer can only be evaluated by constructing wells into it. After construction, the wells are pumped to determine the quality and quantity of groundwater available for use.

**Wildlife** From badgers and beavers to turtles and wild turkeys, Hancock County is teeming with wildlife. Some of the birds you could see are bald eagles, red-winged blackbirds, herons, and bluebirds. Fox, coyote, and deer roam the bluffs and timbered areas, while frogs and nonpoisonous snakes keep close to the riverbanks.

# GUIDE TO THE ROUTE

The starting point for the Hamilton-Warsaw Area field trip is at the Hamilton High School, which is located on the southeast corner of Route 136 (Keokuck Street) and 10th Street in Hamilton. Assemble in the parking lot on the south side of the school. Entrance to the parking lot is at the intersection of 12th and Laurel Streets.

**You must travel in the caravan** Please drive with headlights on while in the caravan. Drive safely but stay as close as you can to the car in front of you. Please obey all traffic signs. If the road crossing is protected by an Illinois State Geological Survey (ISGS) vehicle with flashing lights and flags, please obey the signals of the ISGS staff directing traffic. When we stop, park as close as possible to the car in front of you and turn off your lights.

**Private property** Some stops on the field trip are on private property. The owners have graciously given us permission to visit on the day of the field trip only. Please conduct yourselves as guests and obey all instructions from the trip leaders. So that we may be welcome to return on future field trips, follow these simple rules of courtesy:

- Do not litter the area.
- Do not climb on fences.
- Leave all gates as you found them.
- Treat *public* property as if you were the owner—which you are!

When using this booklet for another field trip with your students, a youth group, or family, remember that *you must get permission from property owners or their agents before entering private property*. No trespassing please.

Four USGS 7.5-Minute Quadrangle Maps (Hamilton, Keokuk, Sutter, and Warsaw) provide coverage for this field trip area.

Miles to next point	Miles from start	
0.0	0.0	Start of field trip is at the exit of the parking lot, Laurel and 12th Streets. TURN LEFT and exit the parking lot onto Laurel Street heading east.
0.1	0.1	Crossroad intersection (Laurel Street and 13th Street). Note: 2-way stop from right and left. CONTINUE AHEAD.
0.1	0.2	STOP (1-way). T-intersection (14th Street/IL Route 96 and Laurel Street). TURN RIGHT onto IL Route 96.
0.05	0.25	Cross Oak Street intersection.
0.05	0.3	Cross Broadway Street intersection.
0.1	0.4	Cross Walnut Street intersection and begin descent into the valley cut by Railroad Creek.

0.3	0.7	CAUTION: Approaching dual set of railroad tracks. Unguarded, signal lights only, no guard gates.
0.1	0.8	Cross railroad tracks.
0.05	0.85	Cross Railroad Creek and begin ascent out of the valley cut by Railroad Creek. Outcrop of Warsaw Shale formation occurs along the banks of the creek.
0.50	1.35	T-intersection from the right (850E and 1220N). CONTINUE AHEAD.
0.85	2.2	Road makes a large, gentle 90° turn to the right.
0.1	2.3	At the middle of the curve is an unmarked intersection from the left. CONTINUE AHEAD on the main road.
0.7	3.0	Begin descent into the large valley cut by Crystal Glen Creek.
0.3	3.3	Cross Crystal Glen Creek. To the left is an outcrop of Warsaw Shale Formation and overlying loess along the west side of the creek bank. After crossing the creek, the road begins ascent uphill.
0.05	3.35	Crossroad intersection (760E and IL Route 96). CONTINUE AHEAD.
0.50	3.85	CAUTION: Prepare to stop; approaching junction of the Great River Road.
0.15	4.0	STOP (4-way) with flashing red light. Crossroad intersection (700E/IL Route 96 and 1090N). CONTINUE AHEAD. Note: You are now on the Warsaw Road. After passing through the intersection begin another descent into a small valley cut by a small tributary of Crystal Glen Creek. The Warsaw Shale Formation is exposed to the right and left along banks of the creek.
0.5	4.5	Crossroad intersection (650E and 1080N). CONTINUE AHEAD.
0.25	4.75	Cross Cedar Glen Creek.
0.25	5.0	To the left, the road is parallel to a small tributary of Cedar Glen Creek. Notice the numerous small slumps along the bank of the creek and the bent tree trunks near their base. This is a good example of an unstable slope with soil creep and slumping.
0.5	5.5	Road makes a sharp 90° turn to the right.
0.25	5.75	T-intersection (550E) from the left. CONTINUE AHEAD. This marks the Corporate Boundary of Warsaw, population 1,900. Note: You are now on Main Street, entering the community of Warsaw.
0.35	6.1	Entrance to Catholic Cemetery on the right. CONTINUE AHEAD.
0.2	6.3	Begin descent into large valley cut by Geode Glen Creek. Note: This creek is unnamed on the 7.5-minute topographic map.

0.3	6.6	Crossroad intersection (20th Street). CONTINUE AHEAD.
0.15	6.75	T-intersection from the right (unmarked). CONTINUE AHEAD.
0.15	6.9	Begin second descent into the valley cut by Geode Glen Creek.
0.1	7.0	Cross Geode Glen Creek. Bedrock of Warsaw Shale formation exposed in the creek bed.
0.1	7.1	T-intersection from the right (unmarked). CONTINUE AHEAD.
0.1	7.2	Crossroad intersection (unmarked). CONTINUE AHEAD.
0.1	7.3	Crossroad intersection (10th Street from the left and the exit from Geode Park to the right). CONTINUE AHEAD.
0.2	7.5	Crossroad intersection ( North 9th Street) TURN RIGHT. Entrance to Geode Park.

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**STOP 1 Geode Park-Geode Glen Creek (Warsaw Formation)** Follow the gravel road past the red barn located on the left. The gravel road makes a large U-shaped curve to the right, past the pavilion, and reconnects with Main Street. Please pull over to the far right side of the gravel road and park your vehicles as close as possible. After parking your vehicle, walk down the old road bed that is located west of the pavilion to the bottom of Geode Glen Creek.

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0.0	7.5	Leave Stop 1. CONTINUE AHEAD on gravel road to the park exit. Near the park exit, to the left, is a wooden log cabin, and to the right is Henerhoff Field. An old school building used to be located where Henerhoff Field is now located.
0.1	7.6	Intersection of Main and 10th Streets, at the park exit. TURN RIGHT.
0.05	7.65	Cross 9th Street intersection. CONTINUE AHEAD.
0.15	7.7	T-intersection (8th Street) from the left. CONTINUE AHEAD.
0.1	7.8	Cross 7th Street intersection. CONTINUE AHEAD.
0.05	7.85	STOP (4-way). Intersection of 6th Street and Main Street. CONTINUE AHEAD. Note: You will be entering the business district of Warsaw when you pass through the stop signs.
0.05	7.9	Cross North 5th Street intersection. CONTINUE AHEAD.
0.1	8.0	Cross North 4th Street intersection. CONTINUE AHEAD.
0.1	8.1	Cross North 3rd Street intersection. CONTINUE AHEAD. Note: Sign indicates that a right turn will take you to the Fort Edwards Monument.

0.05	8.15	Cross North 2nd Street intersection. CONTINUE AHEAD. Road makes a sharp descent toward the Mississippi River floodplain. Notice the man-made limestone walls to the right and the large Victorian homes located along the tops of the bluffs of the Mississippi River. View of the Mississippi River is directly ahead. Also to the right at the base of the bluffs is the Ursa Farmers Coop-Warsaw Grain Elevator.
0.1	8.25	TURN RIGHT at the bottom of the bluffs. Follow the road in front of the elevator and immediately east of the scales. TURN RIGHT again, just past the scales and begin ascent up the bluffs. You are now on Clay Street.
0.1	8.35	Exposure of Pleistocene material to the right. Park on the right side of the road.

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### **STOP 2 Ursa Farmers Coop-Warsaw Grain Elevator (Pleistocene Section)**

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0.0	8.35	Leave Stop 2. CONTINUE AHEAD.
0.05	8.4	STOP (2-way): Intersection of Clay Street and North 2nd Street. CONTINUE AHEAD.
0.05	8.45	STOP (2-way): Intersection of Clay and North 3rd Street. TURN LEFT heading north on 3rd Street.
0.05	8.5	T-intersection (North 3rd Street and Jackson). CONTINUE AHEAD. Note the large valley cut into the bluffs just past the intersection.
0.05	8.55	STOP (2-way): Intersection of North 3rd Street and Van Buren. CONTINUE AHEAD. Ralston Park is located to the right. Note: We will make three right-hand turns, thus "circling the wagons" around Ralston Park.
0.1	8.65	Intersection of North 3rd Street and Polk. TURN RIGHT. Note: If you continue ahead, 3rd Street will take you to the Fort Edwards Monument.
0.1	8.75	Intersection of Polk and 4th Streets. TURN RIGHT
0.1	8.85	Intersection of North 4th Street and Van Buren. TURN RIGHT. Pull over to the curb and park your vehicles. This is Stop 3.

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**STOP 3 Lunch: Ralston Park in Warsaw** After lunch we will walk to the Fort Edwards Monument and the Scenic View of the Mississippi River. Follow 3rd Street north to Fort Edwards Drive.

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**STOP 4 Fort Edwards Monument** Scenic view of the Mississippi River valley and the bluffs on both sides of Old Man River. From the north side of the monument, looking northward, you can look across the Mississippi River and its floodplain and see the limestone bluffs along the left (Iowa) and right (Illinois) sides of the Mississippi River valley. Looking from the north side of the monument, to your right is a large tannish-pink building that looks like a small castle. This was the home of the Warsaw Brewing Company, which closed on February 7, 1972. The brewery was founded on this site in 1861 by Rudolph Giller.

On the sides of the monument:

On the north side: A picture of Fort Edwards with the inscription "William N. S. Ivins. Maker of original drawing."

On the east side: Bronze plaque with a likeness of Governor Ninian Edwards.

On the south side: "Erected September 1914 to commemorate the establishment of Fort Edwards built by Major Zachary Taylor, 3rd U.S. Infantry, September 1814. Was abandoned in July 1824."

On the west side: A bronze figure of Zachary Taylor, "Old Rough and Ready," who later became the 12th U.S. President. Fort Edwards was the westernmost frontier post during the War of 1812.

Note the spalling of thin layers (2–4 mm) that has occurred in the granodiorite near the base of the monument. In addition, there is a large chip of stone missing from the northwest corner of the obelisk near the top.

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Leave Stop 4 and walk back to Ralston Park. We will reset the afternoon mileage for the trip at the intersection of North 3rd Street and Van Buren.

0.0	0.0	Intersection of Van Buren and North 3rd Street. TURN LEFT onto North 3rd Street heading south.
0.05	0.05	Intersection of North 3rd and Jackson Streets. CONTINUE AHEAD. Jackson is a T-intersection from the right.
0.05	0.1	Intersection of North 3rd and Clay Streets. CONTINUE AHEAD.
0.1	0.2	Intersection of Main Street and North 3rd Street. TURN LEFT heading east onto Main Street. On the southeast side of the intersection is the Warsaw City Hall, which is located in the old Hill Dodge & Company building.
0.05	0.25	Intersection of 4th and Main Street. CONTINUE AHEAD. The Farmer State Bank is located on the southeast corner of the intersection.
0.10	0.35	Intersection of 5th and Main Street. CONTINUE AHEAD.
0.05	0.4	STOP (4-way) with flashing red light. Intersection of North 6th and Main Street. TURN LEFT onto North 6th Street. We are now following the North National Route of the Great River Road.
0.05	0.45	Cross intersection of Clay Street. CONTINUE AHEAD.

0.05	0.5	Cross intersection of Jackson Street. CONTINUE AHEAD.
0.05	0.55	Begin descent into the valley cut by Geode Glen Creek.
0.10	0.65	T-intersection (College Street) from the right. CONTINUE AHEAD.
0.15	0.80	T-intersection from the left (unmarked). CONTINUE AHEAD.
0.1	0.9	Fresh slump on the right. Notice the very deep, notched valley that has eroded into the loess that was deposited on top of the bluffs in this area. The old brewery is to the left.
0.20	1.1	Road curves to the right.
0.2	1.3	Mississippian limestones and shales outcrop on right. CAUTION: The shoulder along this outcrop is very soft during the spring and after a heavy rain. This is an <b>extremely hazardous</b> exposure because of loose, rubbly rock and fast moving traffic.
		<p>This is an exposure of the Warsaw Shale, Sonora Formation, and the overlying St. Louis Formation. The upper 15 feet of this exposure belongs to the St. Louis Formation. The exposure consists of light to medium gray, fine grained, smooth, algal limestone that is coarsely brecciated with irregular contorted beds. Some grayish- green shale, especially in the lower part, exhibits squeezing.</p>
		<p>The St. Louis breccia is underlain by the Sonora Formation. The Sonora is a sandy, argillaceous dolomite that is about 15 to 18 inches thick near the middle of the exposure and that weathers brown. Fossils present in the Sonora show that it is equivalent in age to the Salem and the topmost part of the Warsaw in adjacent areas.</p>
		<p>The lower 15 feet of the roadcut exposes the upper part of the Warsaw Shale. It consists of coarsely crystalline, glauconitic, bioclastic (made up of seashell fragments) limestones interbedded with grayish-green laminated shales. Bryozoans are the most common fossil present.</p>
0.25	1.55	Mud Island is to the left in the Mississippi River. Notice the small fishing cottages along the river, and the trailers and campsites located on the left.
0.70	2.25	T-intersection from the right. Entrance to the Alice L. Kibbee Life Science Station, Western Illinois University. CONTINUE AHEAD.
0.15	2.4	Large slump on the right. CAUTION: The shoulder along this slump is very soft during the spring and after a heavy rain. Note the hummocky earthflow topography. Just past the slump is an outcrop of Warsaw Shale covered with a lot of talus.
0.2	2.6	Good exposure of upper part of the Mississippian Keokuk Limestone along the right side of the road.

The upper part of the Keokuk Limestone exposed here consists of gray crinoidal limestone containing gray chert nodules. The uppermost beds are light gray to grayish-tan dolomite that contain a few scattered geodes. Dark gray shale interbeds increase in number in the upper part of the section. Although many of the limestone beds are very fossiliferous, loose, well-preserved fossils are not common. The Keokuk grades upward into the lower part of the Warsaw a short distance farther uphill (west). The Warsaw is composed of grayish-tan to brown biocalcarene limestone that does not contain any geodes.

As you continue to the east and north, notice the decrease in the amount of shale and the increase in the amount of limestone in the roadcuts. The limestones become thicker and more massive, and some contain a considerable amount of chert.

0.35	2.95	Pull off to the right side of the road as far as possible. CAUTION: <b><i>Fast moving traffic. Exit your vehicles from the passenger side.</i></b>
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**STOP 5 Cedar Glen Creek** The small creek to the right is Cedar Glen with an entrenched meander. This sharp meander is entrenched in bedrock, and each loop of the meander is separated by a bedrock wall with a length of 185 feet, a minimum width of 1.75 feet, and a maximum width (measured at the stream where the meander begins) of 12 feet.

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0.0	2.95	Leave Stop 5 and CONTINUE AHEAD.
0.15	3.1	To the right is a small abandoned quarry, which is now owned by The Nature Conservancy (TNC).
0.2	3.3	T-intersection (620E and 1180N) from the Right. CONTINUE AHEAD.
0.1	3.4	Long roadcut in the upper Keokuk Limestone on the right. Exposed is about 25 feet of crinoidal biosparite with nodular beds and lenses of secondary chert.
0.1	3.5	Cross Crystal Glen Creek. This creek contains a number of geodes. Remember you must obtain permission before you enter private property.
0.1	3.6	Continuation of outcrop on other side of Crystal Glen Creek.
0.1	3.7	Cross abandoned railroad tracks. Road begins gentle curve to the right just past the railroad tracks.
0.3	4.0	During high water, backwater from the Mississippi River can be seen on both sides of the road. A small creek flows parallel to the road.
0.7	4.7	Crossing under high-tension power lines.
0.05	4.75	T-intersection (marked as a Dead End) from the right. CONTINUE AHEAD.

0.15	4.9	T-intersection (Warsaw Road and Windy Hills) from the right. CONTINUE AHEAD. Note: Directly ahead on the left is the Great River Redimix cement plant and some limestone and cement spoil piles that are being used to fill in the lowlands. Immediately past the Windy Hills Road is a small secondary entrance to the quarry stockpiles on the right. PREPARE TO TURN RIGHT.
0.15	5.05	TURN RIGHT just beyond the stockpiles. CAUTION: Cross private railroad track, unguarded, no lights, limited rail traffic. Note: Just past the railroad tracks and before the quarry entrance, is a road to the left that leads to the main offices of the quarry company. Directly ahead is the entrance to Gray Quarry. Follow the caravan once we enter the quarry to the bottom of one of the benches.
0.05	5.1	<b>STOP 6 Gray Quarry</b>
0.0	5.1	Leave Stop 6. Retrace your route to the entrance. CONTINUE STRAIGHT AHEAD, cross the private railroad crossing, and make an immediate LEFT TURN in front of the stockpiles located on the left side of road. Follow the railroad tracks to the small unnamed creek. Note: On the day of the field trip, we may walk from the road depending on the conditions of stockpile area and surrounding roads.
0.2	5.3	<b>STOP 7 Gray Quarry Creek</b> Geode collecting stop.
0.0	5.3	Leave Stop 7. Follow the stockpile road around the outside of the stockpile back to Warsaw Road and TURN RIGHT.
0.1	5.4	Passing main entrance of the quarry on the right. CONTINUE AHEAD. CAUTION: Large trucks moving across the road.
0.1	5.5	Cross dual set of railroad tracks; flashing lights, no guard gates. CONTINUE AHEAD.
0.15	5.65	Cross Railroad Creek.
0.05	5.7	STOP (1-way) with flashing red lights. Intersection of (US Route 136/ National Route of the Great River Road and Warsaw Road). TURN RIGHT. Note: There is a right-hand merge line at this intersection. After making a turn, merge to the left as soon as possible. Enter the city of Hamilton as soon as you make the turn. Note: If you turn left, you will cross the Mississippi River and end up in Keokuk, Iowa.
0.2	5.9	T-intersection from the right. CONTINUE AHEAD.
0.1	6.0	T-intersection from the right leads you to the business district of Hamilton. CONTINUE AHEAD. Note: To the left is the home of Dadant & Sons, Beekeepers & Supplies. They sell candles and gifts, beekeeping supplies, and honey.

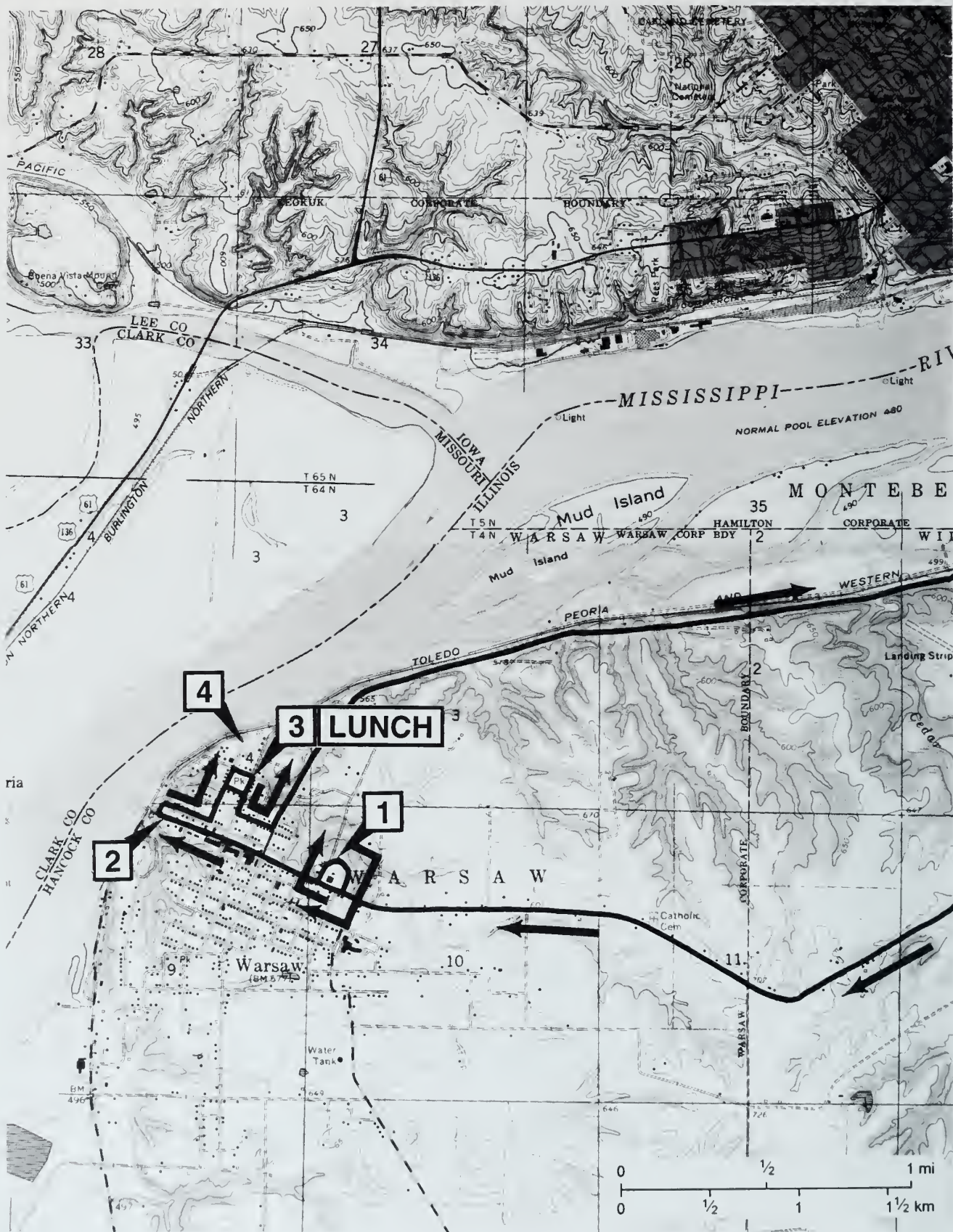
Born in France in 1817, Charles Dadant came to this country with his wife in 1863. He was involved in the raising of bees and the manufacturing of beeswax. When he settled in Hamilton on a 40-acre piece of land north of Hamilton, Dadant's primary goal had been to raise grapes for wine. Due to soil and weather conditions, raising the champagne-type grapes did not look promising. Because of experience in beekeeping in his native land, he imported at the first opportunity Italian bees and purchased hives. He and his son Camille were producing some wine from the vineyards, but their main source of income came from beekeeping. By 1879 they were producing 15,000 pounds of honey. "Ma ma mia! That's a lot of honey!"

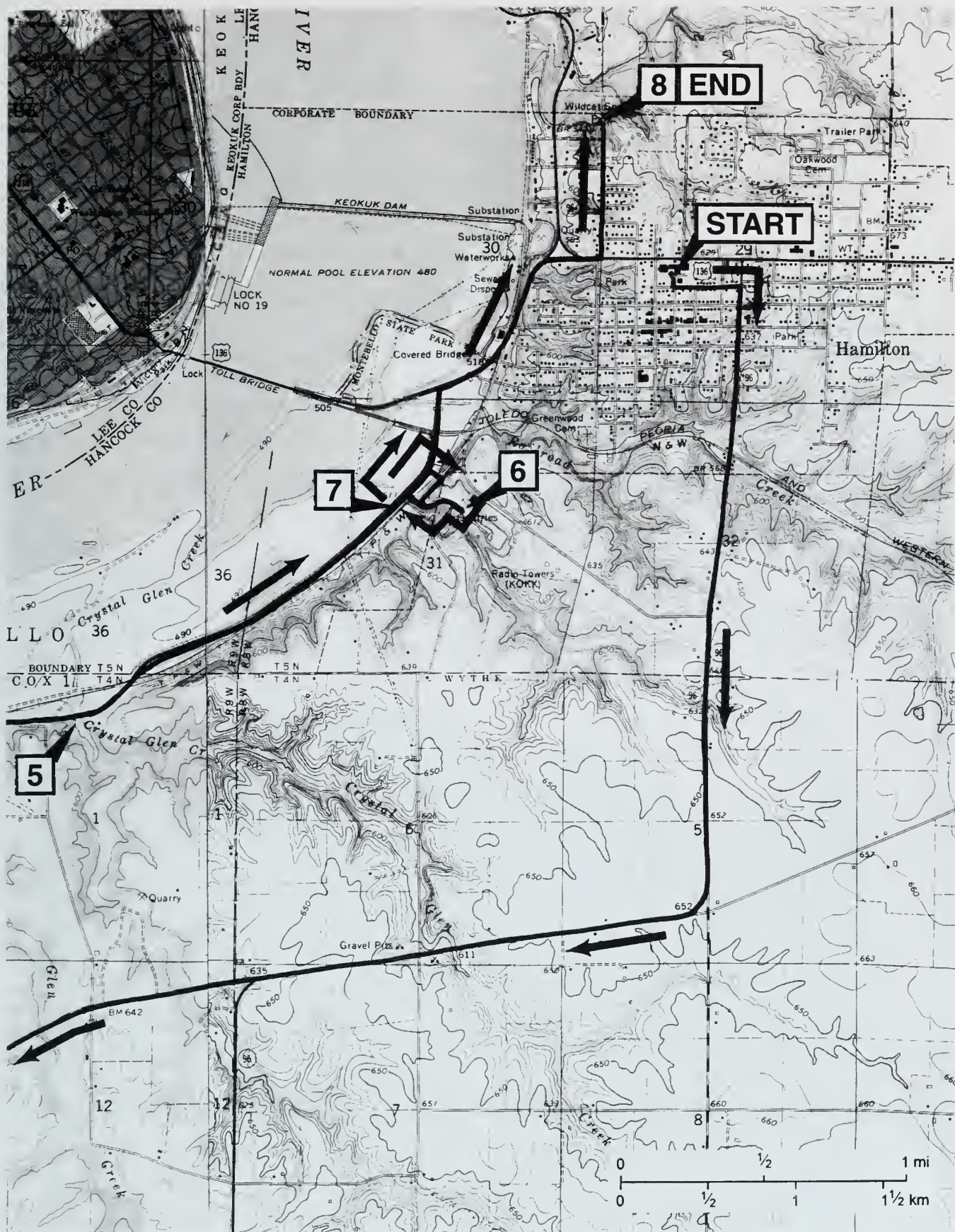
0.1	6.1	Abandoned quarry on the right.
0.05	6.15	View of Keokuk Dam to the left.
0.05	6.2	T-intersection (Laurel Street) from the right. CONTINUE AHEAD.
0.1	6.3	Y-intersection (IL Route 96 and US Route 136). TURN RIGHT. Follow US Route 136.
0.1	6.4	T-intersection (Belmont Drive) from the right. CONTINUE AHEAD.
0.05	6.45	Intersection of 7th Street from the right, with a slight offset to the left. TURN LEFT onto 7th Street and head north toward Wildcat Springs Park.
0.10	6.55	Cross Church Street intersection. CONTINUE AHEAD.
0.10	6.65	Pass Highland Street intersection on the left. CONTINUE AHEAD.
0.05	6.7	Pass Westview Street intersection on the right. CONTINUE AHEAD.
0.1	6.8	Pass Lakeview Road on the left. CONTINUE AHEAD.
0.05	6.85	Enter Wildcat Springs Park. CONTINUE AHEAD.
0.05	6.9	Pass Cooper Street intersection from the left. CONTINUE AHEAD.
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0.1	7.0	<b>STOP 8 Wildcat Springs Park</b> Follow the lower access area road to the left and circle back around toward the entrance.

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**END OF TRIP** Follow 7th Street back to the intersection of US Route 136. Have a safe trip home.

I hope you enjoyed today's outing. Join us again on May 30, 1998, for the Kankakee River State Park Area Geological Science Field Trip.





## STOP DESCRIPTIONS

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**STOP 1 Geode Glen** Type Section of the Warsaw Formation (NW, Sec. 10, T4N, R8W, 4th P.M., Hancock County, Warsaw 7.5-Minute Quadrangle).

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The following stop description has been adapted and modified from Cote and others (1971), Hess (1976), and Collinson (1979).

This stop is the type locality for the Warsaw Formation and the geodes associated with it (fig. 12). The name *Warsaw* was first applied by Hall (1857) to the shale and limestone beds overlying the geode beds, which then were referred to as part of the Keokuk. Later, Hall (1858) included everything between the St. Louis and the geode beds, but in 1908 Stuart Weller recognized the sandy dolomite or dolomitic sandstone at the top of the section as Salem and removed it from the Warsaw. Later, Van Tuyl (1925) included the geode beds with the Warsaw. This type locality was established by Worthen in the 1800s. Van Tuyl (1916), Collinson (1964), Hayes (1964), and Sinotte (1969) have discussed this location in some detail.

The exposed section along Geode Glen Creek divides naturally into the lower Warsaw (or geode beds) and the upper Warsaw (or *Archimedes* beds).

From the starting point at this stop, where the old roadbed crosses Geode Glen Creek, only the lower section of the Warsaw Formation (the geode beds) is exposed. The upper section of the Warsaw Formation (the *Archimedes* beds) is exposed approximately  $\frac{1}{3}$  mile to the east along the creek where an old iron bridge is located. To the west, approximately  $\frac{1}{4}$  mile, where the creek flows under the Warsaw Road, an additional 10 feet of the lower beds is exposed.



Figure 12 Warsaw Shale Formation in Geode Glen – Stop 1 (photo by W. Frankie).

The following descriptions are from the base upward and roughly correspond to the generalized stratigraphic column (fig. 13).

### **Lower Warsaw/Geode Beds**

**Unit 1** – The lowest unit of the lower Warsaw here consists of massive, argillaceous, fine grained dolomite that weathers light tan and contains abundant large silica-type geodes, some in excess of 30 cm. Typically, most of the geodes, however, are smaller. The quartz in these geodes is mostly made up of crystals that grow inward from the outer shell margins. Less secondary quartz and mineralization is seen, and minor sulfides (pyrite and rare chalcopyrite) have been found.

**Unit 2** – This cherty, dark gray-brown dolomitic limestone contains brown chert bands and is up to 3 feet thick. In this unit, geodes are rare except near the base where complex geodes with secondary milky quartz occur. Strata in this interval have been interpreted by geologists as an algal biostromal unit.

**Unit 3** – This interval is made up of mostly gray dolomitic mudstone with some layers of more massive tan-weathering argillaceous dolomite. Near the base of this interval, the following geode varieties, although sporadic in occurrence, have been reported by Hess (1976):

1. Quartz geodes consisting primarily of silica with abundant pyrite or capillary pyrite, which range up to about 15 cm and commonly contain water.
2. Crushed, flattened silica geodes or small geodes with abundant, drusy, doubly-terminated quartz, kaolinite, and local sphalerite. Hayes (1964) and Sinotte (1969) have indicated the sphalerite-rich zones are surrounded by rock with high zinc content (over 700 ppm).
3. Primary silica-type chalcedony-quartz geodes with inner layer of blue, botryoidal chalcedony on primary quartz and pyrite or capillary pyrite.

**Unit 4** – In this zone of the lower Warsaw, geodes become abundant but are smaller in size and rarely exceed 10 cm. The following varieties are noted by Hess (1976):

1. Small, primary, silica-type geodes.
2. Crushed, flattened silica-type geodes with abundant secondary, drusy quartz, kaolinite, and sporadic sphalerite.
3. Small silica-calcite-type geodes with outer chalcedony shell, wall zone of recrystallized brown calcite and quartz, and pink or white scalenohedral calcite, pyrite, and kaolinite on the interior.
4. Small silica-calcite-type geodes with outer chalcedony shell, wall zone of recrystallized brown calcite and quartz, and clear to white rhombohedral calcite, locally enclosing the pink scalenohedrons. Unidentified black stains (possibly produced by heavy petroleum hydrocarbons) occur in some of these geodes. Geodes containing petroleum have been reported from localities north of Hamilton.

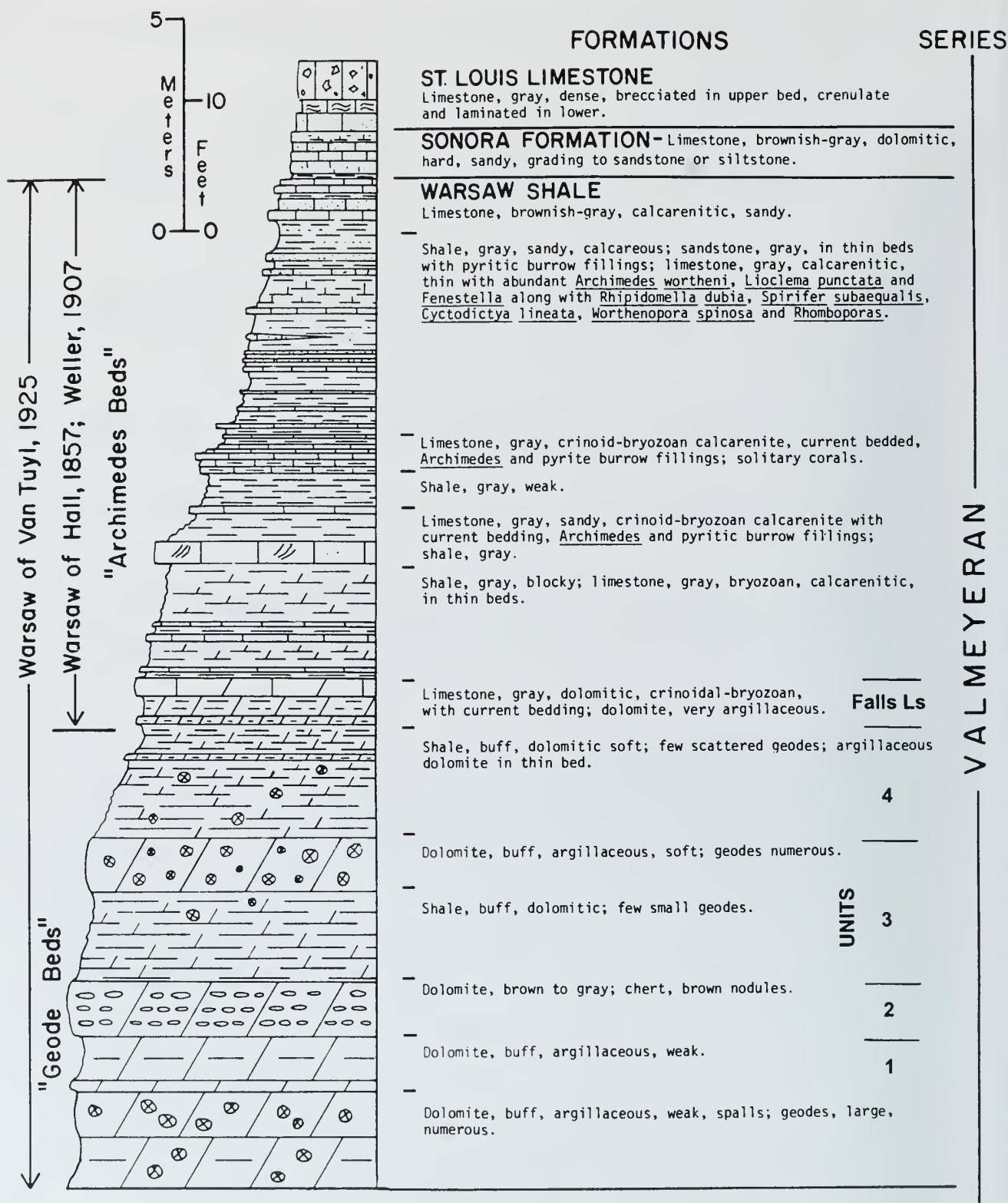


Figure 13 Stratigraphic column of Warsaw type section, Geode Glen – Stop 1 (modified from Collinson et al. 1979).

At higher stratigraphic levels, the geodes become increasingly flattened, and many exhibit invasion of the dolomitic mudstone into the crushed interiors, suggesting that the sediment was still rather soft while the geodes were forming. Certain geodes at all levels have slickensided clay exteriors, suggesting primary formation of the geodes while the sediment was still soft.

**Falls Limestone** – The lower Warsaw (Units 1–4) is separated from the gray mudstone of the upper Warsaw by this dolomitic limestone unit (in the past informally called the falls limestone). No geodes are known in the upper Warsaw, although rare small cavities with brown calcite may occur.

### **Upper Warsaw/*Archimedes* Beds**

*Archimedes wortheni* (the well known “corkscrew”-type bryozoan) occurs in the upper Warsaw Formation. The *Archimedes* beds are exceedingly well exposed, and a few specimens can still be collected. That any remain is a testament to their original abundance, inasmuch as this has been a favorite collecting spot for more than a century. Many other typical marine fossils can also be found in this interval (crinoids, brachiopods, corals, etc.).

Many new fossil species not known in the Keokuk appear in the Warsaw, and—when differences in lithology are taken into account—such changes are not unexpected. Bryozoa dominate the Warsaw with *Leioclema*, *Rhombopora*, *Fenestella*, and *Archimedes* as the main genera. *Echinoconchus alternatus*, *E. biseriatus*, *Camarotoechia mutata*, *Spirifer tenuicostatus*, *Spirifer pellaensis*, *Brachythyris subcardiformis*, *Reticularia setigera*, and *Eumetria verneuliana* are the most common brachiopods. The corals *Triplophyllum dalei* and *Monilipora beecheri* are also common. The fauna of the Sonora is smaller but similar; it has fewer recognized bryozoan species and the same brachiopod fauna.

### **Depositional Environments**

The Warsaw is relatively sandy and pyritic compared to the underlying carbonates. Several thin calcareous or dolomitic sandstone beds are found in the upper Warsaw and may represent an interfingering relationship with the overlying Sonora.

The presence of clay minerals (kaolinite) and heavy minerals led Hayes (1964) to suggest that the Warsaw sea was regressive in the southeastern Iowa–western Illinois area (see *Mississippian Rocks in Illinois* at the end of this guidebook) and the near-shore zone spread from north to south. Kaolinite occurs in the lowest subunit of the Warsaw Formation in the north and increases in abundance upward, but is generally absent in the south, appearing only in the upper subunit of the lower Warsaw. The hypothesis here is that the kaolinite clay was deposited into the shallow seas by rivers that were flowing southward from the exposed terrestrial highlands to the north.

### **Geodes**

A geode is a discrete spheroidal to disk-shaped body with an outer chalcedony shell and an interior that is at least partly crystalline and has crystals growing inward. It may or may not be hollow, depending upon the extent of crystal growth. See Geobit 3 *Geodes—Small Treasure Vaults in Illinois* at the back of this guidebook for more information on geodes.

Geodes are widespread in certain units of Kinderhookian and Valmeyeran (Mississippian) age in the central lowlands area and on the east edge of the Central Basin in Tennessee. The major Mississippian formations in which they occur are:

1. Lower Warsaw Formation and Uppermost Keokuk Limestone  
West-central Illinois, southeastern Iowa, northeastern Missouri
2. Harrodsburg Limestone  
Upper part of Muldrough Formation  
South-central Indiana, north-central Kentucky
3. "Warsaw Formation"  
Fort Payne Chert (Maury Shale member)  
Woodbury, Tennessee area, eastern part of Highland Rim in Tennessee
4. Choteau-Sedalia Formations  
West-central Illinois and east-central Missouri

Geode mineralogy (Sinotte 1969) is dependent upon several factors, including original concretion composition; surrounding rock mineralogy; and groundwater pH, Eh, and fluid composition. Biologic concentration of metals and sulfides is thought to play a part (Hess and Rose 1966).

Several types of geodes have been noted by Hess (1976):

1. Silica-type geodes made of crystallized quartz adjacent to the outer layer of chalcedony. Calcite may be present, but it is always less than 50% by volume. These geodes can be found in all the above-mentioned units. These geodes are typically large, contain no kaolinite, and have singly-terminated quartz euhedra and chalcedony. In the upper part of the lower Warsaw, these geodes are generally small, commonly contain kaolinite, have a flattened shape, and contain secondary (doubly-terminated) quartz.
2. Silica-calcite-type geodes containing quartz euhedra replacing brown calcite with recrystallized calcite forming over 50% by volume. The original concretion silica and clay is reprecipitated as kaolinite and small doubly-terminated quartz crystals. The earliest calcite often is recrystallized brown rhombohedral calcite, followed by pink or white calcite scalenohedrons containing kaolinite, and last by clear or white rhombohedrons of calcite, often enclosing the scalenohedrons as phantoms. The three stages are not seen in all silica-calcite-type geodes. These geodes occur in the upper interval of the lower Warsaw Formation.
3. Calcite geodes with no silica except for the outer chalcedony shell. The brown calcite recrystallized from the original concretion. Only it and secondary clear calcite are present; quartz and kaolinite are absent. This is the rarest type of geode and occurs only in the upper subunit of the lower Warsaw. The brown calcite fluoresces orange and may contain an iridescent coating of stilpnosiderite  $[(\text{Fe}, \text{Ca})\text{CO}_3]$  at some localities.

Hayes (1964) also theorizes that these geode concretions developed early because (1) bedrock laminations curve around geodes, (2) the horizontal axis of geodes is usually parallel to bedding, and (3) slickensides indicate compaction of sediment around geodes.

A comparison of the known geode minerals in the three major geode districts of Middle Mississippian age in the central United States is given in Table 1.

**TABLE 1 MINERALS IN GEODES IN MISSISSIPPIAN AGE FORMATIONS (after Hess 1976)**

<b>Indiana–Kentucky</b>	<b>Illinois–Iowa–Missouri</b>	<b>Woodbury, Tennessee</b>
Erd and Greenberg (1960) Hess and Rose (1966–67)	Sinotte (1972)	Chown and Elkins (1974)
Edwardsville Fm. Harrodsburg Limestone	Warsaw Fm.	Fort Payne Fm. Warsaw Fm.
<b>Silicates</b>	<b>Silicates</b>	<b>Silicates</b>
Chalcedony	Chalcedony	Chalcedony
Quartz (including second generation)	Quartz	Quartz
Kaolinite(?)	Kaolinite	
<b>Carbonates</b>	<b>Carbonates</b>	<b>Carbonates</b>
Calcite	Calcite	Calcite
Aragonite	Aragonite	Dolomite
Ferroan dolomite	Ferroan dolomite	
Ankerite (?)	Stilpnosiderite (Fe, Ca) CO <sub>3</sub>	
Siderite (?)		
Malachite	Malachite	
Smithsonite	Smithsonite	
Strontianite		
<b>Elements</b>		
Sulfur (?)		
<b>Sulfides</b>	<b>Sulfides</b>	<b>Sulfides</b>
Pyrite (scarce)	Pyrite-(common)	Pyrite
Marcasite (scarce)	Marcasite	
Pyrrhotite (low-temp)		
Smythite Fe <sub>3</sub> S <sub>4</sub>		
Sphalerite	Sphalerite	
Chalcopyrite (rare)	Chalcopyrite	
Millerite	Chalcocite (?)	
<b>Sulfates</b>	<b>Sulfates</b>	<b>Sulfates</b>
Barite (common)	Barite scarce)	Anhydrite
Anhydrite	Anhydrite (?)	
Gypsum (selenite)	Gypsum (selenite)	
Celestite		
Green alteration of millerite	Jarosite	
<b>Oxides</b>	<b>Oxides</b>	<b>Oxides</b>
Geothite	Geothite	Geothite
Hematite	Hematite	
Pyrolusite	Pyrolusite	
H <sub>2</sub> O	H <sub>2</sub> O	H <sub>2</sub> O

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**STOP 2 Ursa Farmers Coop-Warsaw Grain Elevator** (NW NW NE, Sec. 9, T4N, R5W, 4th PM, Hancock County, Warsaw 7.5-Minute Quadrangle)

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A recently excavated exposure of Pleistocene deposits occurs directly west of the Ursa Farmers Coop Grain Elevator in Warsaw, Illinois (fig. 14). The deposits are being excavated and removed for use as fill material. The following measured section was made during preparation for this field trip. This exposure, like many others in the area, may become covered by a talus slope and overgrown within a short period of time.

**Measured Section**

- 1.0 ft Modern Soil – developed in the loess
- 6.0 ft Windblown silt deposit (Peoria Silt) – a loess deposit
- 1.0 ft Light gray silty zone – possibly a paleohydric soil
- 3.3 ft Black, organic-rich, silty to clay sand, blocky with light and dark gray blebs – interpreted as a paleo A Horizon soil profile –Yarmouth Soil
- 1.5 ft Medium gray, fine grained sand and silt, with local oxidized reddish rizospheres – interpreted as a paleo B Horizon soil profile
- 1.5 ft Maximum thickness of a mixed sand and gravel deposit, fining upward, and pinching out to the right and left – interpreted as a channel deposit
- 1.4 ft Reddish, oxidized, sandy to pebbly zone, up to 3 feet thick
- 0.6 ft Sandy, gray zone
- 0.5 ft Yellowish to orangish-yellow, clay-rich till – Banner Formation
- (base is covered)

Scattered throughout the lower portion of the exposure and in the surrounding piles of worked material are several large erratics up to 1 foot in diameter.

The Pleistocene deposits in the immediate vicinity of the town of Warsaw have been mapped by Lineback (1979) and generally consist of Pre-Illinois Glacial Episode deposits belonging to the Banner Formation. The Banner Formation consists mostly of till, but includes small areas of outwash sands and gavels and lacustrine silt and clay. Sand and gravel facies, like the one exposed at this stop, are common along the tributaries of the Mississippi River in this area, and have been interpreted to be remnants of old river terraces. The sand and gravel unit at this stop may represent either a glacial outwash deposit or an old terrace deposit. More field work and detailed mapping in this area are needed to resolve which interpretation is correct. The interpreted paleosoil at this stop is most likely the Yarmouth Soil, which formed during the interglacial period between the Pre-Illinois and Illinois Glacial Episodes. The overlying loess deposit was formed during the later Wisconsin Glacial Episode.



**Figure 14** Pleistocene deposits at Ursa Farmers Coop-Warsaw Grain Elevator – Stop 2 (photo by W. Frankie).

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**STOP 3 Lunch Stop: Ralston Park** (SW SE SE and SE SW SE, Sec. 4, T4N, R9W, 4th PM, Hancock County, Warsaw 7.5-Minute Quadrangle) *Are you hungry?*

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**STOP 4 Fort Edwards Monument** (NE SW SE, Sec. 4, T4N, R9W, 4th PM, Hancock County, Warsaw 7.5-Minute Quadrangle) on bluff overlooking the Mississippi River.

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The Fort Edwards Monument, which was erected in September 1914, commemorates the establishment of the fort in September 1814 by Zachary Taylor of the Third U.S. Infantry. The fort was abandoned in July 1824 (fig. 15).

### **Mississippi Valley History (fig. 16 )**

During the Pleistocene Epoch, commonly referred to as the “Great Ice Age,” an extensive continental ice cap developed in the northern hemisphere during times when the mean annual temperatures were a few degrees cooler than now. The portion of the ice cap that intermittently covered northern North America has been named the Laurentide Ice Sheet. The ice that entered Illinois and the Midwest came from centers of heavy snow accumulations in central and eastern Canada. Beginning about 1.6 million years ago and ending only about 13,500 years ago, southward expansions of the ice sheet produced three or more major glacial invasions into Illinois and the Midwest. In order of occurrence, these glaciations have been named the Pre-Illinois, the Illinois, and the Wisconsin Glacial



**Figure 15** Fort Edwards monument – Stop 4 (photo by W. Frankie).

Episodes, denoting the states where glacial deposits of these ages are best developed or were first described (see *Pleistocene Glaciations in Illinois*, at the back of the guidebook). Each of the glacial advances, which produced significant changes in the topography and drainage of the glaciated areas, was followed by long, warm interglacial intervals during which the glaciers melted away completely. During these interglacial intervals, deposits left by the glaciers were eroded and weathered. The last glacier, the Wisconsin Glacial Episode, melted from northeastern Illinois only 13,500 years ago.

River valleys, such as those of the Mississippi, Illinois, and Ohio Rivers, provided major channel-ways for escaping meltwaters. These valleys were greatly widened and deepened in the bedrock during times of greatest meltwater floods. When the meltwaters were waning, the valleys were partially filled with outwash far beyond the ice margins. Many former river valleys in areas covered by the glaciers were completely filled and buried by glacial deposits. The meltwaters also cut new valleys and caused numerous changes—some temporary, others permanent—in the drainage system.

The field trip area was covered, at least in part, by glaciers of the Pre-Illinois and Illinois Glacial Episodes. The Pre-Illinois glacier advanced from the northwest and the Illinois glacier from the northeast. Pre-Illinois and Illinois Glacial Episodes deposits are well represented in Hancock County. The Mendon



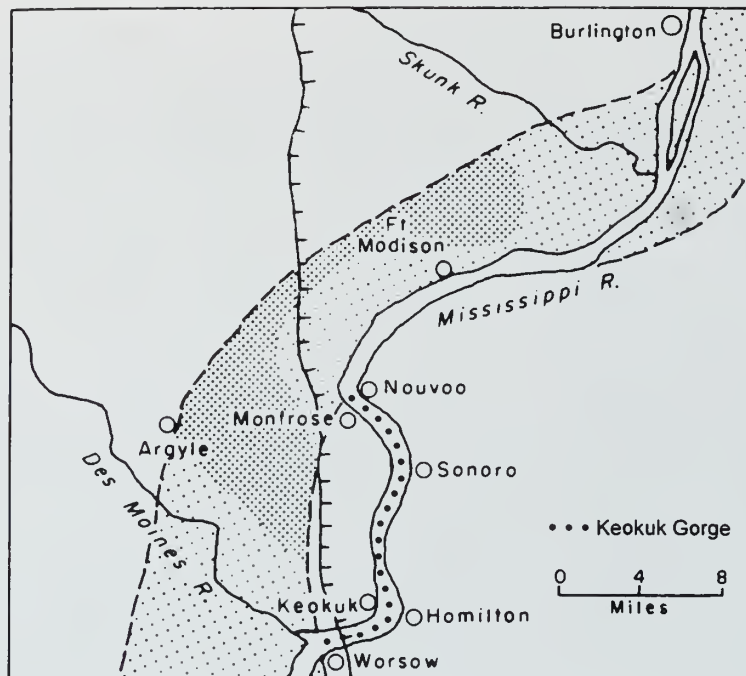
**Figure 16** Mississippi River valley from Fort Edwards Site, looking to the northeast – Stop 4 (photo by W. Frankie).

Moraine, an end moraine that marks the line of maximum advance of the Illinois Episode glacier, crosses the region southeastward from the vicinity of Warsaw. Although the Wisconsin glaciers did not cover this area, windblown loess derived from outwash valley-train deposits mantles the bluffs and uplands

This vantage point provides a magnificent view of the Mississippi River valley, by far the most prominent topographic feature in this portion of the field trip area. To the northeast at Keokuk, the river emerges from a narrow, bedrock-walled and bedrock-floored gorge barely wider than the river itself. Within the Keokuk Gorge, which begins at Nauvoo (fig. 17), about 15 miles to the north, the river flows over bedrock, or at least it did before the Keokuk dam was built. Over a stretch of 11 miles above Keokuk, the river flowed over a series of rapids cut into the Mississippian Keokuk Limestone. These rapids, in which the river had a fall of about 24 feet, presented a barrier to navigation. They were known as the “lower rapids” and also as the “Des Moines rapids,” after the Des Moines River, which enters the valley just south of Keokuk.

South of the mouth of the Des Moines River, the Mississippi River valley widens abruptly to a very large size. The valley plain, which can be seen directly ahead to the west, is 8 miles wide at this point. The valley also widens considerably from Nauvoo northward. There, on the Illinois side, the river is bounded by rocky bluffs, but on the Iowa side, the bluffs are cut entirely into glacial drift. From Fort Madison southward to Montrose (fig.17), the west valley bluff swings in a great arc, and the flat river valley is at its maximum width of 5 miles.

The small size of the Keokuk Gorge in relation to the vast size of the Mississippi River valley above and below the rapids was first noted by geologists in the 1850s. At that time, they correctly



**Figure 17** Generalized map of the Ancient Iowa Valley prior to the Illinois glacier (coarse dots within dashed lines) and the present course of the Mississippi River. The buried portion of the old valley is shaded. The Illinois Glacial Episode margin is shown by the hachured line (modified from Cote 1970).



**Figure 18** West-to-east cross section of abandoned Ancient Iowa Valley and the Mississippi River valley from Argyle, Iowa, to Sonora, Illinois. Thick glacial deposits in the buried valley are shown by shading (modified from Cote 1970).

recognized that the gorge was much younger than the wider portions of the valley and that a stream diversion had occurred as a result of glacial activity. The abandoned portion of the old valley, which is largely buried by glacial deposits, was discovered several miles to the west of the present gorge. This buried valley, partially re-excavated by the present Mississippi and its tributaries, the Skunk and Des Moines Rivers, extends in a great arc from north of Fort Madison to west of Keokuk (fig.17). The old valley, with a width of more than 6 miles and a depth of nearly 300 feet, is approximately ten times the size of the new gorge (fig. 18). The floor of the buried valley is 125 to 135 feet below the rock floor of the gorge.

Prior to the diversion that cut the Keokuk Gorge, the old valley was occupied by an ancestral stream called the Ancient Iowa River. The Ancient Iowa River headed near Muscatine and flowed southward along a course approximately the same as that followed on the west side of Illinois by the present Mississippi River. The course of the Ancient Mississippi River lay farther east. The Ancient Mississippi River cut a valley that entered Illinois at Fulton and extended southeastward to the present “Big Bend” of the Illinois River near Hennepin. From there the Ancient Mississippi River followed approximately the present course of the Illinois River valley to a junction with the Ancient Iowa valley near Grafton in Calhoun County. Both the Ancient Iowa and Ancient Mississippi Rivers are believed to have originated as meltwater streams during the Pre-Illinois glacial and interglacial intervals.

The diversion of the Ancient Iowa River, which cut the lower rapids, is believed to have occurred as a result of the Pre-Illinois glaciation, because the drift that fills the abandoned portion of the valley is mostly Pre-Illinois in age. In the bluffs on the Iowa side at Fort Madison, 100 feet of Pre-Illinois till is exposed. In contrast, the Illinois glacier covered only part of the old valley at its maximum advance. At the maximum extent of the Pre-Illinois glacier, the Ancient Iowa River valley along most of its course was completely covered by the ice, and drainage was diverted eastward into the Ancient Mississippi Valley. When the Pre-Illinois Glacial Episode melted back, the Ancient Iowa River reoccupied most of its Pre-Illinois valley, but the loop of the valley westward from Nauvoo to below Keokuk was covered by the ice long enough for the river to entrench itself in the bedrock—thus forming the Keokuk Gorge.

During the Illinois Glacial Episode, the Ancient Iowa and the Mississippi Rivers were again forced from their valleys to courses farther to the west in Iowa. However, this Illinois Glacial diversion was only temporary, and when the ice front melted back, both rivers resumed their previous courses. The Keokuk Gorge was deepened by meltwaters as the river eroded its valley during the Illinois and Wisconsin glacial episodes. During the Woodfordian advance of the Wisconsin glaciation, the Ancient Mississippi River was forced westward and permanently diverted into the Ancient Iowa Valley when meltwater overtopped another bedrock divide at Cordova in Rock Island County. The old valley to the “Big Bend” was buried by drift and permanently abandoned. The Illinois River then assumed the valley of the Ancient Mississippi to the south.

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**STOP 5 Cedar Glen Creek** Entrenched Meanders at the Alice Kibbe Field Station, Warsaw, Illinois (NE, Sec. 2 and W½ of Sec.1, T4N, R9W, 4th P.M., Hancock County, Warsaw 7.5-Minute Quadrangle)

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Cedar Glen Creek is located approximately 2.75 miles east of the center of Warsaw, Illinois, on the Alice Kibbe Field Station, property of the Department of Biological Sciences, Western Illinois University. It was acquired in 1954 through the estate of Dr. Alice Kibbe, noted teacher and botanist for many years at Carthage College, formerly located in Carthage, Illinois. The area is noted for a wide range of wildlife habitats including prairie grasslands, sand barrens, upland oak-hickory-maple forest, moist forest types on rich limestone soil slopes, and Mississippi bottomland forest and marshland. The Field Station and adjoining areas form a winter refuge for the bald eagle, and on winter days from December to late March, they can be observed fishing along the river, especially just below Keokuk Dam.

Cedar Glen Creek drains into the Mississippi River (see route map). Near its mouth, a regime marked by alternating riffles and pools is characteristic. However, immediately upstream and to the south of the Great River Road highway, spectacular meanders have been entrenched into the Keokuk Limestone.



**Figure 19** Neck cutoff called “Hanging Bridge” in Cedar Glen Creek – Stop 5. View is upstream from the meander loop on the east side of the Hanging Bridge (photo by W. Frankie).

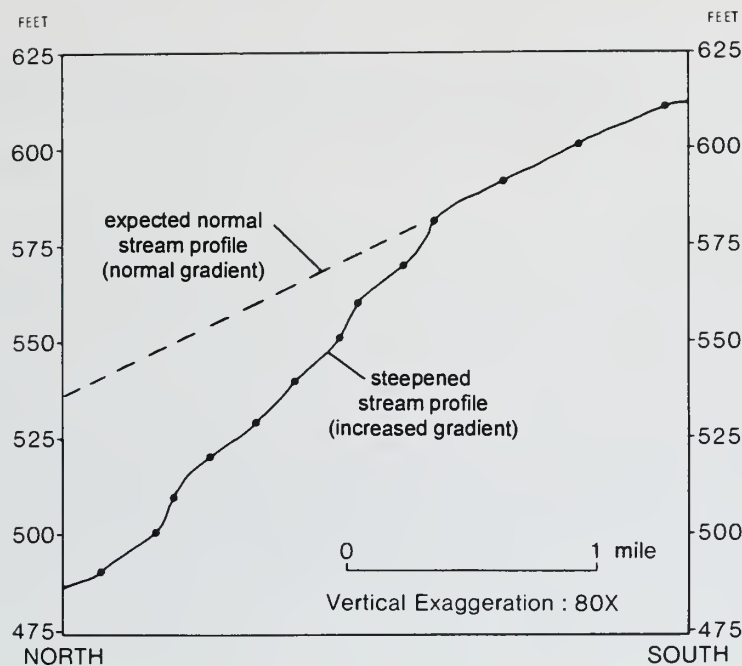
The last meander downstream is virtually a neck cutoff and is famous in Dr. Alice Kibbe's book, *Botanical Survey of a Typical Midwestern County*, as “Hanging Bridge” (p. 64). This cutoff has a length of 185 feet with a minimum width of 1.75 feet and a maximum width of 12 feet (fig. 19). Hess (1976) suggested that a pronounced break in the stream gradient at this point and the higher migrational velocity of the upstream meanders have contributed to the development of this neck cutoff.

Cliffs in the Keokuk limestone are spectacular features and reach a maximum relief of 90–100 feet. Spectacular undercut banks with “chutes” are present at the base of many of these cliffs and indicate pronounced lateral as well as downward cutting by Cedar Glen Creek.

The bedload of the stream is made up chiefly of sand-sized particles; pebbles, cobbles, and boulders of Keokuk limestone; and pebbles and cobbles of chert. Minor constituents include quartz geodes; calcite concretions locally containing chalcopryrite, sphalerite, millerite (rare), or polydymite (rare); and boulders and cobbles of glacial till. Composition of the stream-worked till includes granitic gneiss, amphibolite, greenstone, diorite, gabbro, anorthosite, syenite, and chert. Lower reaches of the stream have Keokuk limestone bedrock at the surface. Glacial till is present on the upper reaches of Cedar Glen Creek.

The profile shape of Cedar Glen Creek is worth noting (fig. 20). The upper reaches exhibit a normal, gently concave upward profile. This profile steepens notably at 580 feet elevation, the approximate beginning of the meander system. The steepening continues to an elevation of 490 feet, the approximate elevation of the Mississippi River floodplain at this point.

The northernmost tributary, which empties into Cedar Glen Creek from the west, has a similar profile shape, with incised meanders and meander necks well developed in the lower reaches of this



**Figure 20** Stream profile of Cedar Glen Creek shows normal and steepened gradients (modified from Hess 1976).

tributary. However, although other tributaries to the south steepen somewhat, there is little or no evidence of these meanders there.

Crystal Glen and "Gray Quarry" Creek to the east exhibit similar, but less spectacular entrenched meanders. However, other streams to the southwest (near Warsaw) lack this feature, and have a steep but normal stream profile.

Cedar Glen Creek and probably Crystal Glen Creek were ice-marginal streams that fed the Ancient Iowa River (Leverett 1899) during the later stages of the Illinois Glacial Episode. At that time, the Mississippi River was flowing in what is now the Illinois River valley, and the Ancient Iowa River flowed several miles to the west of the present Mississippi River valley. Cedar Glen Creek, at that time, may have had a gentler gradient and well-developed meanders. However, when the western course of the Ancient Iowa River was diverted eastward to the present bedrock gorge in the Keokuk area, the drainage course was shortened, the gradient was increased, and the stream was forced to incise its meanders into bedrock. The southernmost tributary of Cedar Glen Creek apparently shared in this history. Subsequent periods of aggradation and down-cutting probably reflect post-Illinois, Wisconsin, and post-Wisconsin glacial history of the region. For example, a prominent niche in some cliffs at approximately 530 feet elevation may represent a period of aggradation during the development of this stream valley and the Mississippi River.

The southern upstream reaches of Cedar Glen Creek, upstream tributaries of Crystal Glen Creek, and other streams in the area have more normal profiles lacking incised meanders. These drainage courses probably developed at a time subsequent to the eastward diversion of the Ancient Iowa River.

Almost the entire Keokuk Limestone is exposed near the mouth of the creek (fig. 21). The Keokuk here consists chiefly of four rock types:

# FORMATIONS AND MEMBERS

SERIES

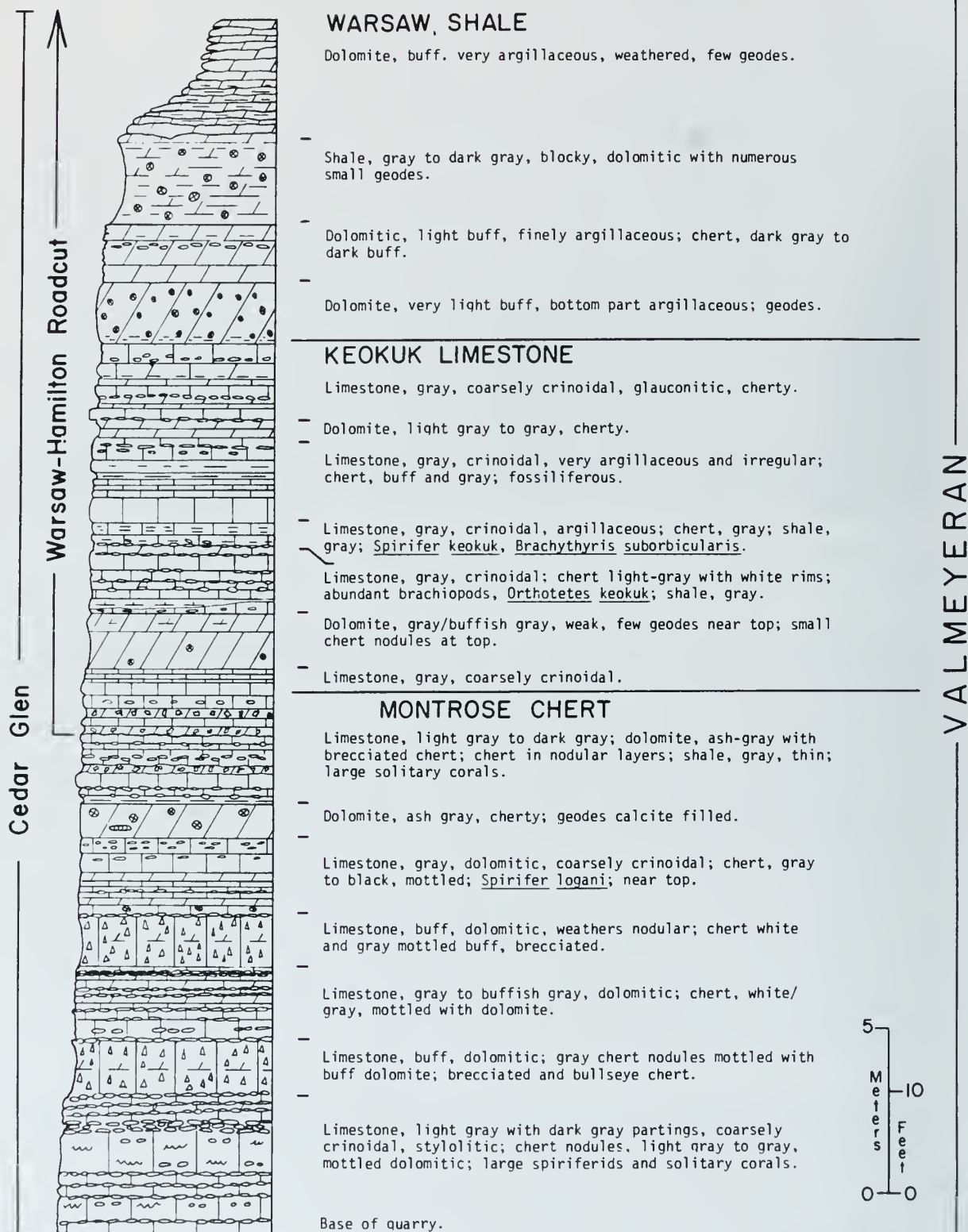


Figure 21 Stratigraphic column of Warsaw Shale, Keokuk Limestone, and Montrose Chert in Geode Glen and adjacent roadcut – Stop 5 (modified from Collinson et al. 1979).

1. Biosparite limestone that is rich in pelmatozoans; layers are rich in tetracorals and spiriferid and productid brachiopods, and contain minor trilobites, fish dental plates, and bryozoans.
2. Lenses and layers of blue-gray to white chert.
3. Thin layers of gray dolomitic fine grained lime mudstone.
4. Gray-brown, fine grained argillaceous dolomite with calcite concretions, locally containing sulfide inclusions.

The Montrose Chert member of the Keokuk is located at the base of the outcrop in the creek bed and is characterized by abundant mottled and brecciated chert in buff dolomite, interbedded with light buff crinoidal limestone. The overlying beds of the Keokuk consist of gray to dark gray, coarse calcarenite lithology. The upper Keokuk beds are exposed in the roadcut. In addition to several dolomitic zones, the upper unit contains a number of broad zones that vary in the amount of chert. Most of the chert is gray and there are several fish tooth beds. A 3-inch, dark gray calcarenite bed lies about 8 feet above the lowest beds of the roadcut; it also contains abundant brachiopod and crinoid remains.

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**STOP 6 Gray Quarry** (SW NE, Sec. 31, T5N, R8W, 4th PM, Hancock County, Hamilton 7.5-Minute Quadrangle) (fig. 22)

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Twenty years ago, the main quarry exposed all but the lowermost few feet of the Keokuk Limestone. Now the rest of the Keokuk Limestone, all of the Burlington Limestone, as well as the underlying Kinderhookian (lower Mississippian) North Hill Group (Starrs Cave, Prospect Hill, and McCraney Limestones) and New Albany Group (Hannibal Shale) are also exposed (figs. 11 and 23). The freshness of exposures makes the quarry proper a difficult spot for fossil collecting, but many marine fossils are found, especially in the Burlington and Keokuk Limestones.

**Hannibal Shale** – Near the bottom of the quarry, as much as 30 feet of the silty facies of the Kinderhookian Hannibal Shale are exposed. This silty, limestone to calcareous siltstone at one time was known as the English River Siltstone. It is very dark gray, fine grained, quite shaley, with “massive” bedding, wavy shaley partings, small limestone clasts, and scattered brachiopod casts. It is quite bioturbated and is very soft and silty in the lower portion.

**McCraney Limestone** – The Hannibal Shale is in turn overlain by nearly 40 feet of McCraney Limestone of the Kinderhookian North Hill Group. The McCraney consists of alternating thin layers of light gray to buff lithographic limestone and buff to brown, very fine grained dolomite. A bed of coarse oolite forms the top of the McCraney where the formation is at its thickest (in this region of the state). Many vugs, filled with nice sparry calcite and dolomite rhombs, are also common.

**Prospect Hill Siltstone** – The McCraney is in turn overlain by the Prospect Hill Siltstone, which is nearly 30 feet thick. The Prospect Hill is composed of a siltstone, light gray to buff, that is calcareous, pyritic, massive, and quite friable. It contains a few macrofossils (mostly fragments of brachiopods and bryozoans), but abundant conodonts (microfossils) are known. Near the middle and base, we see some very shaley limestones in this unit.



**Figure 22** Gray Quarry, looking west – Stop 6 (photo by W. Frankie).

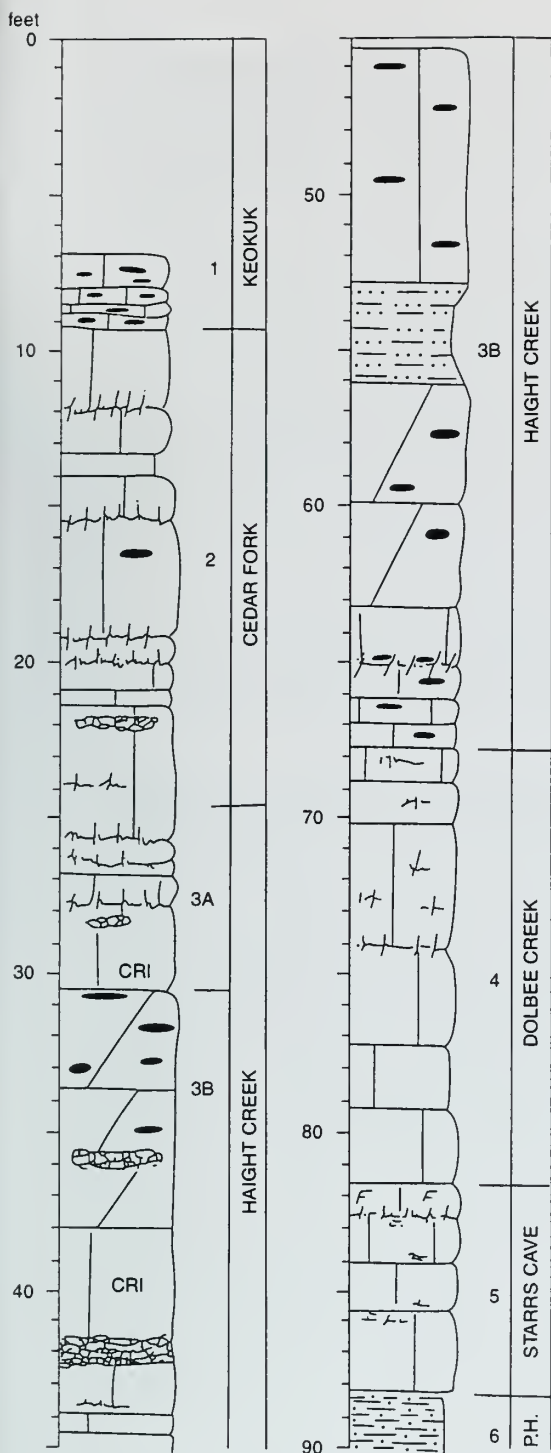
**Starrs Cave Limestone** – The last formation in the North Hill Group, the Starrs Cave Limestone immediately overlies the Prospect Hill Siltstone in this quarry. This limestone is generally buff to light brownish gray, coarsely oolitic, and locally dolomitic. It contains abundant marine fossils, dominated by brachiopods.

**Burlington Limestone** – Between 70 to 80 feet of Burlington Limestone are found in this quarry directly overlying the Starrs Cave Limestone. The Burlington is characterized in this area by very pure, coarsely crystalline, light gray limestone in medium to thick beds. It may contain some beds of fine grained, brownish gray dolomitic limestone. In addition, beds and nodular masses of light gray or white chert are common, especially in the middle and upper parts of the formation. A few beds are glauconitic (a greenish clay mineral that gives a greenish cast to the rocks). Crinoid fragments, particularly crinoid stems, are especially abundant, and a fair number of beds are composed entirely of such clasts. The top of the unit is supposedly marked by a bed up to nearly 1 foot thick that contains many fish teeth and spines.

Both the Burlington and the overlying Keokuk are interpreted to represent a shallow-water, mostly clastic-dominated, carbonate sediment that formed on the western flank of the Illinois Basin while the Borden delta was expanding into the basin from the north and east.

Abundant fossils restricted to the Burlington include the blastoids *Cryptoblastus melo* and *Globoblastus norwoodi*, many crinoids too numerous to mention, and the brachiopods *Dictyoclostus burlingtonensis*, *Rhipidomella burlingtonensis*, *Stenocisma bisinunata*, *Spirifer grimesi* and *s. forbesi*, and *Spiriferella plena*.

**Keokuk Limestone** – The Keokuk Limestone occurs throughout much the same area as the underlying Burlington Limestone and, as mentioned, represents part of a series of shallow-water, fossil fragment-rich carbonate sediments that formed on the western shelf of the Illinois Basin. It is well



MISSISSIPPIAN KEOKUK LIMESTONE		
Bed		Feet
1	Limestone, lt. gray with chert nodules, fine grained.	2.2
BURLINGTON LIMESTONE CEDAR FORK MEMBER		
2	Limestone, Lt. tan to gray-tan, fine to coarse grained; massive bedded; stylolitic; fossiliferous, some scattered gray-white chert nodules; can be argillaceous.	15.2
HAIGHT CREEK MEMBER		
3A	Limestone, gray, mottled with tan, fine-grained, wavy argillaceous layers on bedding scattered planes, numerous crinoid, bryozoan and bachiopod fragments; scattered gray and white nodules, stylolitic.	6.0
3B	Dolomite and Limestone, tan mottled with gray fine to medium-grained, scattered fossil fragments, may have shaley limestone and calcareous siltstone 3.0 feet thick near middle, numerous gray and white chert nodules with some pyrite and glauconite, vuggy in lower portion.	37.0
DOLBEE CREEK MEMBER		
4	Limestone, light gray-tan, lithographic; thin bedded at top, more massive in lower half, stylolitic in upper half; scattered fossil fragments throughout.	14.0
KINDERHOOKIAN SERIES—NORTH HILL GROUP STARRS CAVE LIMESTONE		
5	Limestone, gray-tan, fine to coarse grained; massive bedded; sandy and argillaceous; scattered pyrite crystals; wavy shale partings and narrow stylolites common; scattered fossils.	6.5
PROSPECT HILL SILTSTONE		
6	Calcareous shale and siltstone, dark gray-green matrix, with gray limestone clasts and seams; fossiliferous; interbedded with gray limestone, gray, fine-grained; massive bedded; wavy black shale seams on bedding planes; some fossils.	9.0

Figure 23 Generalized stratigraphic column for Gray Quarry – Stop 6.

exposed along the bluffs along the Mississippi River in this area, where it is typically 60 to 80 feet thick. At this quarry, records we examined indicate it may be up to 100 feet thick. Like the underlying Burlington Limestone, the Keokuk Limestone is primarily a formation made up of clastic carbonate sediments composed primarily of shell fragments. (This type of rock is called a biocalcarene.) In this quarry, the lower 30 feet is known as the Montrose Chert Member (because of abundant chert).

Fish teeth and representatives of the brachiopods *Orthis keokuk*, *Spirifer keokuk* and *Brachythyris suborbicularis* are fairly common in the upper part of the quarry in the Keokuk. The giant productid brachiopod *Marginirugos magnus*, which is restricted to the uppermost Keokuk, is occasionally found. A number have been collected along a railway cut not far south of the quarry. Conodonts are common in almost every limestone bed in the Keokuk and are abundant in beds halfway between the base of the Keokuk and the top of the quarry. *Gnathodus texanus* predominates.

The lower level of the Keokuk (Montrose Chert member) is characterized by brecciated and mottled dolomitic chert in great abundance. Above the Montrose Chert, the Keokuk is a gray to dark gray crinoid and bryozoan calcarenite with interspaced buff dolomite beds. Gray chert occurs throughout the section. The formation becomes increasingly shaley upward and grades into the argillaceous dolomite of the overlying Warsaw. The uppermost significant calcarenite bed is usually picked as the top of the Keokuk. The Keokuk–Warsaw contact is about 12 feet below the upper lip of the quarry.

**Warsaw Shale** – Almost the entire thickness of the Warsaw geode beds is preserved here, but only the lower geode horizon is well exposed. The upper geode horizon is represented by a lag concentration of small geodes just below the Pleistocene deposits.

Hayes (1964) has established that geodes (1) appear to be confined to the lower Warsaw, (2) are associated with argillaceous dolomites and dolomitic mudstones, (3) occur in zones or beds, (4) initially were round in shape, and (5) are conformable with laminations in the enclosing rock. He also indicates that there is a tendency toward uniformity in size in each zone and that pyrite distribution is associated with geode distribution. Geodes usually consist of a chalcedonic shell and an inner layer of crystals that range from quartz and calcite to pyrite, ankerite, magnetite, hematite, kaolin, aragonite, millerite, chalcopyrite, sphalerite, limonite, smithsonite, malachite, gypsum, fluorite, barite, marcasite, goethite, and pyrolusite. Such a variety has not been noted here, but excellent calcite and quartz geodes are common.

On top of the Warsaw, a short Pleistocene section is especially well exposed at the north edge of the property.

Pleistocene Series	Thickness
<b>Wisconsinan Stage</b>	
<i>Peoria Loess</i> – silt, light tan in upper 3 feet, gray- and tan-mottled below, leached, tough	8 ft
<i>Roxana Silt</i> – silt, brown to orange tan, leached, tough	2 ft
<b>Illinoian Stage</b>	
<i>Till</i> – gray, pebbly, deeply weathered and highly oxidized to red brown, Fe- and Mn-stained, heavy, clayey (Sangamon Soil)	2 ft

The Illinoian till is thin, perhaps because of post-Illinoian erosion. It is intensely weathered and poorly exhibits the properties of till. The Sangamon Soil has a distinctive reddish brown color. The soil extends down into the Warsaw Shale for 3 to 4 feet. The Wisconsin loesses are thoroughly leached in this exposure and are very compact and tough.

Gray Quarries opened this pit in 1937 and is presently owned and operated by W.L. Miller, Inc. Overburden, or cover, amounts to about 40 feet. Pit trucks dump the coarse rock from the operating face into the primary crusher. The material then is screened or sieved to produce various sizes of limestone aggregate ranging from riprap to roadstone to agricultural limestone.

Crushed stone (limestone and dolomite) is Illinois' most important mineral resource. Illinois ranks second in production of crushed stone among the 49 producing states. An estimated 72.6 million tons of stone was produced in Illinois in 1992. The total value of this commodity was estimated at \$322.8 million in 1992. During 1991, stone was produced in 53 of Illinois' 102 counties.

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**STOP 7 Gray Quarry Creek** (Note: irregular section, NW, Sec. 31, T5N, R8W, 4th P.M., Hancock County, Hamilton 7.5-Minute Quadrangle)

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"Gray Quarry" Creek is an informal name used to locate the creek that flows along the southeastern edge of Gray Quarry. Exposures of the Warsaw Shale and Keokuk Limestone occur along this creek. A large number of geodes can be found in the gravel deposits within the creek. In addition to the geodes, a number of fossils can be found. The bedload of the stream is identical to that of Cedar Glen Creek, except that it contains a significant amount of additional manmade materials (trash). The sediments consist chiefly of a mixture of sand-sized particles; pebbles, cobbles, and boulders of Keokuk and Warsaw limestone; and pebbles and cobbles of chert. Minor constituents include quartz geodes; calcite concretions locally containing chalcopyrite, sphalerite, millerite (rare), or polydymite (rare); and boulders and cobbles of glacial till. Composition of the stream-worked till, which has been eroded from the overlying Pleistocene deposits, includes granitic gneiss, amphibolite, greenstone, diorite, gabbro, anorthosite, syenite, and chert.

Notice the similarity between this creek and Cedar Glen Creek at Stop 5. Both creeks are deeply entrenched into the limestone bedrock and have sharp meanders near the junction of the bluffs and the adjacent Mississippi River floodplain.

Have fun collecting, but remember to leave some for the next visitor. Remember, you must gain permission to collect here after today's field trip.

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**STOP 8 Wildcat Springs Park** (located at the intersection of Sections 19, 20, 29, and 30, T5N, R8W, 4th PM, Hancock County, Hamilton 7.5-Minute Quadrangle).

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Chaney Creek flows through the middle of Wildcat Springs Park. Exposures of Warsaw Shale and Keokuk Limestone occur along the sides of the creek. The spring is located approximately 0.15 miles east of the 7th Street entrance to the park on the south side of Chaney Creek (see route maps).



**Figure 24** Wildcat Spring in Wildcat Springs Park – Stop 8 (photo by W. Frankie).

Wildcat Spring has developed along the contact between the overlying Warsaw Shale and the underlying Keokuk Limestone (fig. 24). The development of this spring was created by the flow of groundwater within the Warsaw Shale. As the groundwater moved through the Warsaw Shale, it encountered a nonporous limestone bed of the underlying Keokuk Limestone. The flow of water was concentrated along this bedding plane, and over time the shale was eroded and transported to the face of the bluff, where it was deposited into Chaney Creek. A small cave has developed in the bluffs where the spring flows into Chaney Creek. A similar small spring is also visible in the eastern high wall in Gray Quarry.

Geodes, fossils, and glacial erratics can be collected within the gravel deposits along Chaney Creek.

## Wildcat Springs

The following has been modified from *History of Hamilton, Illinois*, by Judith L. Kammerer (Journal Printing Company, Carthage, IL).

Wildcat Springs, a spacious and beautiful park on the north side of Hamilton, has an interesting history. It was hailed as the "picnic paradise of noble forest, with lagoon, a natural cave, ice-cold spring, rocky precipice and spacious terrace, capable of beautiful landscaping as Hamilton grows into metropolitan embellishments." The park was also known as "the favorite and frequent pleasure resort of adjacent cities." Proprietor of the popular spot was one Homer D. Brown, a native of Quincy, Illinois. Mr. Brown, the owner of Montebello Nurseries, was the manager of Wildcat Springs, beginning in the 1880s. Many churches and organizations utilized the park, and Mr. Brown charged a fee for park usage (10 cents for adults and 5 cents for children), with a special fee for groups. The name "Wildcat Springs" was born out of a legend that the last wildcat in that area was killed there.

Chaney Creek meanders through Wildcat Springs, and is popular spot for wading, fishing, and rock-hunting. There are many hiking trails, too, in addition to playgrounds, picnic and camping areas, and the municipal swimming pool. It is no longer legal to swim in Chaney Creek.

Wildcat Springs was a gathering place for barbeques, pageants, and the Hamilton Chautauquas, which were held at Wildcat Springs from 1905 to 1909. Chatauquas were ten-day events that featured lectures on many topics, musical programs, and skits. Out-of-towners became tent campers for the duration. A barbeque was an event of the 6th of September, in the year 1900. There is no record of the big occasion other than the amount of food served: 1,200 pounds of beef, four hogs, four sheep, twenty-five pounds of sweet potatoes, five hundred loaves of bread, and two barrels of pickles. A bit larger than your average picnic, wouldn't you say?

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## GLOSSARY

The following definitions are adapted in total or in part from several sources; the principal source is R.L. Bates and J.A Jackson, eds., *Glossary of Geology*, 3rd ed.: American Geological Institute, Alexandria, VA, 1987, 788 p.

**Ablation** - Separation and removal of rock material and formation of deposits, especially by wind action or the washing away of loose and soluble materials.

**Age** - An interval of geologic time; a division of an epoch.

**Aggrading stream** - One that is actively depositing sediment in its channel or floodplain because it is being supplied with more load than it can transport.

**Alluviated valley** - One that has been at least partially filled with sand, silt, and mud by flowing water.

**Alluvium** - A general term for clay, silt, sand, gravel, or similar unconsolidated sorted or semisorted sediment deposited during comparatively recent time by a stream or other body of running water.

**Anticline** - A convex-upward rock fold in which strata have been bent into an arch; the strata on either side of the core of the arch are inclined in opposite directions away from the axis or crest; the core contains older rocks than does the perimeter of the structure.

**Aquifer** - A geologic formation that is water-bearing and which transmits water from one point to another.

**Argillaceous** - Said of rock or sediment that contains, or is composed of, clay-sized particles or clay minerals.

**Arenite** - A relatively clean quartz sandstone that is well sorted and contains less than 10% argillaceous material.

**Base level** - Lower limit of erosion of the land's surface by running water. Controlled locally and temporarily by the water level of stream mouths emptying into lakes, or more generally and semipermanently by the level of the ocean (mean sea level).

**Basement complex** - The suite of mostly crystalline igneous and/or metamorphic rocks that generally underlies the sedimentary rock sequence.

**Basin** - A topographic or structural low area that generally receives thicker deposits of sediments than adjacent areas; the low areas tend to sink more readily, partly because of the weight of the thicker sediments; the term also denotes an area of relatively deep water adjacent to shallow-water shelf areas.

**Bed** - A naturally occurring layer of earth material of relatively greater horizontal than vertical extent that is characterized by physical properties different from those of overlying and underlying materials. It also is the ground upon which any body of water rests or has rested, or the land covered by the waters of a stream, lake, or ocean; the bottom of a stream channel.

**Bedrock** - The solid rock (sedimentary, igneous, or metamorphic) that underlies the unconsolidated (non-indurated) surface materials (for example, soil, sand, gravel, glacial till, etc.).

**Bedrock valley** - A drainageway eroded into the solid bedrock beneath the surface materials. It may be completely filled with unconsolidated (non-indurated) materials and hidden from view.

**Braided stream** - A low-gradient, low-volume stream flowing through an intricate network of interlacing shallow channels that repeatedly merge and divide, and are separated from each other by branch islands or channel bars. Such a stream may be incapable of carrying all of its load. Most streams that receive more sediment load than they can carry become braided.

**Calcarenite** - Describes a limestone composed of more or less worn fragments of shells or pieces of older limestone. The particles are generally sand-sized.

- Calcareous** - Said of a rock containing some calcium carbonate ( $\text{CaCO}_3$ ), but composed mostly of something else; (synonym: limey).
- Calcining** - The heating of calcite or limestone to its temperature of dissociation so that it loses its carbon dioxide; also applied to the heating of gypsum to drive off its water of crystallization to make plaster of paris.
- Calcite** - A common rock-forming mineral consisting of  $\text{CaCO}_3$ ; it may be white, colorless, or pale shades of gray, yellow, and blue; it has perfect rhombohedral cleavage, appears vitreous, and has a hardness of 3 on the Mohs scale; it effervesces (fizzes) readily in cold dilute hydrochloric acid. It is the principal constituent of limestone.
- Chert** - Silicon dioxide ( $\text{SiO}_2$ ); a compact, massive rock composed of minute particles of quartz and/or chalcedony; it is similar to flint, but lighter in color.
- Clastic** - Said of rocks composed of particles of other rocks or minerals, including broken organic hard parts as well as rock substances of any sort, transported and deposited by wind, water, ice or gravity.
- Closure** - The difference in altitude between the crest of a dome or anticline and the lowest structural or elevation contour that completely surrounds it.
- Columnar section** - A graphic representation, in the form of one or more vertical column(s), of the vertical succession and stratigraphic relations of rock units in a region.
- Conformable** - Said of strata deposited one upon another without interruption in accumulation of sediment; beds parallel.
- Delta** - A low, nearly flat, alluvial land form deposited at or near the mouth of a river where it enters a body of standing water; commonly a triangular or fan-shaped plain extending beyond the general trend of a coastline.
- Detritus** - Loose rock and mineral material produced by mechanical disintegration and removed from its place of origin by wind, water, gravity, or ice; also, fine particles of organic matter, such as plant debris.
- Disconformity** - An *unconformity* marked by a distinct erosion-produced irregular, uneven surface of appreciable relief between parallel strata below and above the break; sometimes represents a considerable time interval of nondeposition.
- Dolomite** - A mineral, calcium-magnesium carbonate ( $\text{Ca,Mg}[\text{CO}_3]_2$ ); also the name applied to sedimentary rocks composed largely of the mineral. It is white, colorless, or tinged yellow, brown, pink, or gray; has perfect rhombohedral cleavage; appears pearly to vitreous; effervesces feebly in cold dilute hydrochloric acid.
- Drift** - All rock material transported by a glacier and deposited either directly by the ice or reworked and deposited by meltwater streams and/or the wind.
- Driftless Area** - A 10,000-square-mile area in northeastern Iowa, southwestern Wisconsin, and northwestern Illinois where the absence of glacial drift suggests that the area may not have been glaciated.
- End moraine** - A ridge or series of ridges formed by accumulations of drift built up along the outer margin of an actively flowing glacier at any given time; a moraine that has been deposited at the lower or outer end of a glacier.
- Epoch** - An interval of geologic time; a division of a period. (Example: Pleistocene Epoch).
- Era** - The unit of geologic time that is next in magnitude beneath an eon; it consists of two or more periods. (Example: Paleozoic Era).

**Escarpment** - A long, more or less continuous cliff or steep slope facing in one general direction; it generally marks the outcrop of a resistant layer of rocks, or the exposed plane of a fault that has moved recently.

**Fault** - A fracture surface or zone of fractures in Earth materials along which there has been vertical and/or horizontal displacement or movement of the strata on opposite sides relative to one another.

**Flaggy** - Said of rock that tends to split into layers of suitable thickness for use as flagstone.

**Flood plain** - The surface or strip of relatively smooth land adjacent to a stream channel produced by the stream's erosion and deposition actions; the area covered with water when the stream overflows its banks at times of high water; it is built of alluvium carried by the stream during floods and deposited in the sluggish water beyond the influence of the swiftest current.

**Fluvial** - Of or pertaining to a river or rivers.

**Formation** - The basic rock unit, one distinctive enough to be readily recognizable in the field and widespread and thick enough to be plotted on a map. It describes the strata, such as limestone, sandstone, shale, or combinations of these and other rock types. Formations have formal names, such as Joliet Formation or St. Louis Limestone (Formation), generally derived from the geographic localities where the unit was first recognized and described.

**Fossil** - Any remains or traces of a once-living plant or animal preserved in rocks (arbitrarily excludes Recent remains); any evidence of ancient life. Also used to refer to any object that existed in the geologic past and for which evidence remains (for example, a fossil waterfall)

**Friable** - Said of a rock or mineral that crumbles naturally or is easily broken, pulverized, or reduced to powder, such as a soft and poorly cemented sandstone.

**Geology** - The study of the planet Earth that is concerned with its origin, composition, and form, its evolution and history, and the processes that acted (and act) upon it to control its historic and present forms.

**Geophysics** - Study of the Earth with quantitative physical methods. Application of the principles of physics to the study of the earth, especially its interior.

**Glaciation** - A collective term for the geologic processes of glacial activity, including erosion and deposition, and the resulting effects of such action on the Earth's surface.

**Glacier** - A large, slow-moving mass of ice formed on land by the compaction and recrystallization of snow.

**Gradient** - A part of a surface feature of the Earth that slopes upward or downward; the angle of slope, as of a stream channel or of a land surface, generally expressed by a ratio of height versus distance, a percentage or an angular measure from the horizontal.

**Igneous** - Said of a rock or mineral that solidified from molten or partly molten material (that is, from magma).

**Indurated** - Said of compact rock or soil hardened by the action of pressure, cementation and, especially, heat.

**Joint** - A fracture or crack in rocks along which there has been no movement of the opposing sides (see also *Fault*).

**Karst** - Collective term for the land forms and subterranean features found in areas with relatively thin soils underlain by limestone or other soluble rocks; characterized by many sinkholes separated by steep ridges or irregular hills. Tunnels and caves formed by dissolution of the bedrock by groundwater honeycomb the subsurface. Named for the region around Karst in the Dinaric Alps of Croatia where such features were first recognized and described.

**Lacustrine** - Produced by or belonging to a lake.

**Laurasia** - A protocontinent of the Northern Hemisphere, corresponding to Gondwana in the Southern Hemisphere, from which the present continents of the Northern Hemisphere have been derived by separation and continental displacement. The supercontinent from which both were derived is Pangea. Laurasia included most of North America, Greenland, and most of Eurasia, excluding India. The main zone of separation was in the North Atlantic, with a branch in Hudson Bay; geologic features on opposite sides of these zones are very similar.

**Lava** - Molten, fluid rock that is extruded onto the surface of the Earth through a volcano or fissure. Also the solid rock formed when the lava has cooled.

**Limestone** - A sedimentary rock consisting primarily of calcium carbonate (the mineral, calcite). Limestone is generally formed by accumulation, mostly in place or with only short transport, of the shells of marine animals, but it may also form by direct chemical precipitation from solution in hot springs or caves and, in some instances, in the ocean.

**Lithify** - To change to stone, or to petrify; especially to consolidate from a loose sediment to a solid rock.

**Lithology** - The description of rocks on the basis of their color, structure, mineral composition, and grain size; the physical character of a rock.

**Local relief** - The vertical difference in elevation between the highest and lowest points of a land surface within a specified horizontal distance or in a limited area.

**Loess** - A homogeneous, unstratified accumulation of silt-sized material deposited by the wind.

**Magma** - Naturally occurring molten rock material generated within Earth and capable of intrusion into surrounding rocks or extrusion onto the Earth's surface. When extruded on the surface it is called lava. The material from which igneous rocks form through cooling, crystallization, and related processes.

**Meander** - One of a series of somewhat regular, sharp, sinuous curves, bends, loops, or turns produced by a stream, particularly in its lower course where it swings from side to side across its valley bottom.

**Meander scars** - Crescent-shaped swales and gentle ridges along a river's flood plain that mark the positions of abandoned parts of a meandering river's channel. They are generally filled in with sediments and vegetation and are most easily seen in aerial photographs.

**Metamorphic rock** - Any rock derived from pre-existing rocks by mineralogical, chemical, and structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment at depth in Earth's crust (for example, gneisses, schists, marbles, quartzites, etc.)

**Mineral** - A naturally formed chemical element or compound having a definite chemical composition, an ordered internal arrangement of its atoms, and characteristic crystal form and physical properties.

**Monolith** - (a) A piece of unfractured bedrock, generally more than a few meters across. (b) A large upstanding mass of rock.

**Moraine** - A mound, ridge, or other distinct accumulation of glacial drift, predominantly till, deposited in a variety of topographic land forms that are independent of control by the surface on which the drift lies (see also *End Moraine*).

**Morphology** - The scientific study of form, and of the structures and development that influence form; term used in most sciences.

**Natural gamma log** - One of several kinds of measurements of rock characteristics taken by lowering instruments into cased or uncased, air- or water-filled boreholes. Elevated natural gamma radiation levels in a rock generally indicate the presence of clay minerals.

**Nickpoint** - A place with an abrupt inflection in a stream profile, generally formed by the presence of a rock layer resistant to erosion; also, a sharp angle cut by currents at base of a cliff.

**Nonconformity** - An unconformity resulting from deposition of sedimentary strata on massive crystalline rock.

**Outwash** - Stratified glacially derived sediment (clay, silt, sand, gravel) deposited by meltwater streams in channels, deltas, outwash plains, on flood plains, and in glacial lakes.

**Outwash plain** - The surface of a broad body of outwash formed in front of a glacier.

**Oxbow lake** - A crescent-shaped lake in an abandoned bend of a river channel. A precursor of a meander scar.

**Pangea** - The supercontinent that existed from 300 to 200 million years ago. It combined most of the continental crust of the Earth, from which the present continents were derived by fragmentation and movement away from each other by means of plate tectonics. During an intermediate stage of the fragmentation, between the existence of Pangea and that of the present widely separated continents, Pangea was split into two large fragments, *Laurasia* on the north and *Gondwana* in the southern hemisphere.

**Ped** - Any naturally formed unit of soil structure (for example, granule, block, crumb, or aggregate).

**Peneplain** - A land surface of regional scope worn down by erosion to a nearly flat or broadly undulating plain.

**Period** - An interval of geologic time; a division of an era (for example, Cambrian, Jurassic, Tertiary).

**Physiography** - The study and classification of the surface features of Earth on the basis of similarities in geologic structure and the history of geologic changes.

**Physiographic province (or division)** - (a) A region, all parts of which are similar in geologic structure and climate and which has consequently had a unified geologic history. (b) A region whose pattern of relief features or landforms differs significantly from that of adjacent regions.

**Point bar** - A low arcuate ridge of sand and gravel developed on the inside of a stream meander by accumulation of sediment as the stream channel migrates toward the outer bank.

**Radioactivity logs** - Any of several types of geophysical measurements taken in bore holes using either the natural radioactivity in the rocks, or the effects of radiation on the rocks to determine the lithology or other characteristics of the rocks in the walls of the borehole. (Examples: natural gamma radiation log; neutron density log).

**Relief** - (a) A term used loosely for the actual physical shape, configuration, or general unevenness of a part of Earth's surface, considered with reference to variations of height and slope or to irregularities of the land surface; the elevations or differences in elevation, considered collectively, of a land surface (frequently confused with topography). (b) The vertical difference in elevation between the hilltops or mountain summits and the lowlands or valleys of a given region; "high relief" has great variation; "low relief" has little variation.

**Rift** - A long narrow trough, generally on a continent, bounded by normal faults, a graben with regional extent. Formed in places where the forces of plate tectonics are beginning to split a continent. (Example: East African Rift Valley).

**Sediment** - Solid fragmental matter, either inorganic or organic, that originates from weathering of rocks and is transported and deposited by air, water, or ice, or that is accumulated by other natural agents, such as chemical precipitation from solution or secretion from organisms. When deposited, it generally forms layers of loose, unconsolidated material (for example, sand, gravel, silt, mud, till, loess, alluvium).

**Sedimentary rock** - A rock resulting from the consolidation of loose sediment that has accumulated in layers (for example, sandstone, siltstone, mudstone, limestone).

- Shoaling** - Said of an ocean or lake bottom that becomes progressively shallower as a shoreline is approached. The shoaling of the ocean bottom causes waves to rise in height and break as they approach the shore.
- Sinkhole** - Any closed depression in the land surface formed as a result of the collapse of the underlying soil or bedrock into a cavity. Sinkholes are common in areas where bedrock is near the surface and susceptible to dissolution by infiltrating surface water. Sinkhole is synonymous with "doline," a term used extensively in Europe. The essential component of a hydrologically active sinkhole is a drain that allows any water that flows into the sinkhole to flow out the bottom into an underground conduit.
- Slip-off slope** - Long, low, gentle slope on the inside of a stream meander. The slope on which the sand that forms point bars is deposited.
- Stage, substage** - Geologic time-rock units; the strata formed during an age or subage, respectively. Generally applied to glacial episodes (for example, to the Woodfordian Substage of the Wisconsin Stage).
- Stratigraphy** - The study, definition, and description of major and minor natural divisions of rocks, particularly the study of their form, arrangement, geographic distribution, chronologic succession, naming or classification, correlation, and mutual relationships of rock strata.
- Stratigraphic unit** - A stratum or body of strata recognized as a unit in the classification of the rocks of Earth's crust with respect to any specific rock character, property, or attribute or for any purpose such as description, mapping, and correlation.
- Stratum** - A tabular or sheet-like mass, or a single, distinct layer of material of any thickness, separable from other layers above and below by a discrete change in character of the material or by a sharp physical break, or by both. The term is generally applied to sedimentary rocks, but could be applied to any tabular body of rock. (See also *Bed*)
- Subage** - A small interval of geologic time; a division of an age.
- Syncline** - A convex-downward fold in which the strata have been bent to form a trough; the strata on either side of the core of the trough are inclined in opposite directions toward the axis of the fold; the core area of the fold contains the youngest rocks. (See also *Anticline*).
- System** - A fundamental geologic time-rock unit of worldwide significance; the strata of a system are those deposited during a period of geologic time (for example, rocks formed during the Pennsylvanian Period are included in the Pennsylvanian System).
- Tectonic** - Pertaining to the global forces that cause folding and faulting of the Earth's crust. Also used to classify or describe features or structures formed by the action of those forces.
- Tectonics** - The branch of geology dealing with the broad architecture of the upper (outer) part of Earth; that is, the major structural or deformational features, their origins, historical evolution, and relations to each other. It is similar to structural geology, but generally deals with larger features such as whole mountain ranges, or continents.
- Temperature-resistance log** - A borehole log, run only in water-filled boreholes, that measures the water temperature and the quality of groundwater in the well.
- Terrace** - An abandoned floodplain formed when a stream flowed at a level above the level of its present channel and floodplain.
- Till** - Unlithified, nonsorted, unstratified drift deposited by and underneath a glacier and consisting of a heterogeneous mixture of different sizes and kinds of rock fragments.
- Till plain** - The undulating surface of low relief in an area underlain by ground moraine.
- Topography** - The natural or physical surface features of a region, considered collectively as to form; the features revealed by the contour lines of a map.

**Unconformable** - Said of strata that do not succeed the underlying rocks in immediate order of age or in parallel position. A general term applied to any strata deposited directly upon older rocks after an interruption in sedimentation, with or without any deformation and/or erosion of the older rocks.

**Unconformity** - A surface of erosion or nondeposition that separates younger strata from older strata; most unconformities indicate intervals of time when former areas of the sea bottom were temporarily raised above sea level.

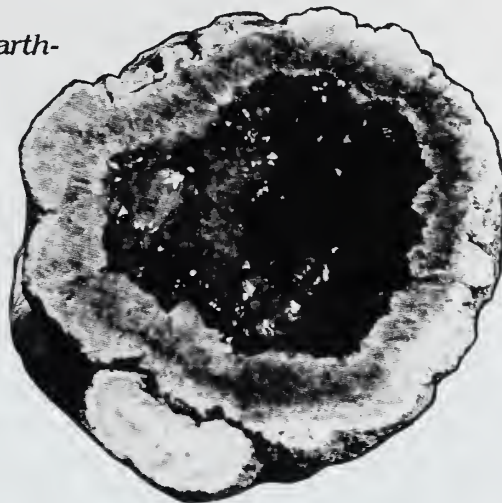
**Valley trains** - The accumulations of outwash deposited by rivers in their valleys downstream from a glacier.

**Water table** - The point in a well or opening in the Earth where groundwater begins. It generally marks the top of the zone where the pores in the surrounding rocks are fully saturated with water.

**Weathering** - The group of processes, both chemical and physical, whereby rocks on exposure to the weather change in character, decay, and finally crumble into soil.

## GEODES—Small Treasure Vaults in Illinois

*Geodes, a term derived from a Greek word meaning earth-shaped, are irregular, roughly spherical bodies. They can be oblong or shaped like invertebrate fossils (e.g. crinoid calyx). Some are hollow and lined with beautiful layers and clusters of various mineral crystals, but others are completely filled by inward-growing crystals. Hollow geodes, relatively light-weight compared with those completely filled, are more desirable because they generally contain a greater variety of minerals that have grown well-formed crystals. Some of Illinois' most beautiful and unusual mineral specimens can be found in the crystal linings of geodes.*



### Where we find geodes

Geodes found in Illinois range from less than 1 inch to more than 2 feet in diameter, but 3 to 5 inches is the average. They generally occur in limestone, a calcium carbonate ( $\text{CaCO}_3$ ), or in dolomite, a calcium-magnesium carbonate ( $\text{CaMg}(\text{CO}_3)_2$ ). Although geodes can be found in carbonate-rich rocks throughout the state, one of the most famous geode collecting areas in the country is in a region of western Illinois and adjacent parts of Iowa and Missouri. The region encompasses about a 70-mile radius from the towns of Warsaw, Hamilton, and Nauvoo.



### What's in a geode?

A typical geode from western Illinois has an outer shell of chalcedony, a type of cryptocrystalline quartz composed of silicon dioxide ( $\text{SiO}_2$ ). Once the outer shell forms, mineral-rich water still inside the shell may cause more quartz to be deposited and other minerals to form toward the center. Chalcedony, much harder than the host rock of limestone, helps to preserve the specimen during weathering. As the weaker host rock is eroded, the geodes "weather out" and remain behind. They generally are easy to see because of their shape and the texture of their outer shell.

The micro-environment inside the shell is an excellent place for crystal growth. Temperature and pressure changes, as well as evaporation, cause the mineral matter to precipitate. More solutions rich in minerals may seep into the geode later, adding to the quartz crystals or forming other minerals. In addition to the chalcedony of the outer shell, the insides of some geodes are lined with a pronounced bumpy, mammillary form of blue-gray chalcedony. Some specimens also have excellent clear quartz crystals. Ankerite, aragonite, calcite, dolomite, goethite/limonite, gypsum, and marcasite/pyrite are the other minerals most commonly found. Occasionally, dark bronze, fine, hair-like masses are found inside; these may be millerite ( $\text{NiS}$ ) or a filament-like form of pyrite.

Perhaps the most fascinating geodes are those that contain petroleum, which may be under enough pressure to squirt out when the geode is broken. The enclosing rock north of Nauvoo, where these unusual geodes are found, no longer contains any significant oil. So what is the source of oil in these geodes? What is the origin of the other minerals? We don't know for sure. Perhaps trace amounts of some of the elements that make up the rarer minerals were present in shale layers associated with the carbonate strata. As a matter of fact, the most prolific zone for collecting geodes in western Illinois is in the lower part of the Warsaw Shale of the Valmeyeran Series (middle series of the Mississippian System). These sedimentary strata were deposited in shallow seas that covered what is now the midcontinent about 350 million years ago.

## How geodes form

Geologists have proposed several theories to explain the conditions and processes that form geodes, but none seems to be entirely adequate to explain all geode features. In discussing the origin of the western Illinois geodes, Hayes (1964) noted that any theory proposed must explain why the geodes are

- essentially confined to a specific stratigraphic interval, the lower part of the Warsaw Shale;
- usually associated with particular lithologies (clayey, shaley dolomite, and dolomitic mudstone);
- located in specific zones or beds rather than scattered randomly;
- fairly uniform in size in a particular zone and round, at least initially;
- enveloped by laminations in the bedrock that exhibit some thinning of layers above and below the specimen.

As limey sediments accumulated in shallow midcontinental seas, rounded cavities that are characteristic of geodes could not have existed at the interface or contact of water and sediments. Nor could they have existed during the earliest stages of sediment compaction and cementation. Therefore, some feature of a different texture than the host limestone had to be present. This feature either caused geodes to form or was transformed into a geode. Hayes hypothesized that the only features in the rocks that shared enough characteristics with geodes to serve as precursors were calcite concretions (small zones in the original sediment strongly cemented by calcite). The size and shape of these concretions, their position in the limestone, and their relation to the surrounding rocks are strikingly similar to those of geodes. In several exposures in the region, rock samples may be found that display all stages of the transition from concretion to geode. Hayes suggested that calcite concretions formed where organic materials (remains of the living tissues of plants or animals) accumulated with carbonate-rich sediments under quiet-water conditions. The organic matter decomposed, causing an oxygen-poor (anaerobic), alkaline environment ( $\text{pH} > 7$ ) to develop in the sediments. These conditions encouraged calcite to precipitate from solutions in the sediments.

The formation of many features seen in geodes may involve a step-by-step replacement of these concretions by quartz and other minerals. Changes in the chemical composition and acidity ( $\text{pH}$ ) of water in the sediments caused chalcedony to replace the calcite at the outer margins of the concretions. This process caused the formation of a calcite-concretion core surrounded by a hard, but

slightly permeable, shell of chalcedony. Further changes in the composition and  $\text{pH}$  of the water percolating slowly through the sediment caused the core concretion inside the geode eventually to dissolve, leaving a hard, hollow cavity in which more chalcedony, quartz, or other minerals could precipitate.

*Contributed by David L. Reinertsen,  
D. Scott Beaty, and Jonathan H. Goodwin*



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# **OIL PRODUCTION IN HANCOCK COUNTY**

**Bryan G. Huff**

Hancock County is one of the lesser oil-producing counties in Illinois; it has probably provided less than 40,000 of the 3.5 billion barrels of oil produced in Illinois since 1905. The county contains only part of one oil field: the westernmost portion of the Colmar-Plymouth field (located north of Plymouth, Illinois, along the eastern county boundary). Discovered in 1914, Colmar-Plymouth is one of the oldest oil fields in Illinois, although production was not established in Hancock County until the late 1920s or early 1930s. Production is from the Devonian Hoing Sandstone, which in this area is from 2 to 5 feet thick and approximately 375 feet deep. Twenty-two wells have been completed as oil wells in the county. Petroleum is also known to occur inside geodes from the Mississippian Warsaw Shale in Hancock County, but this source is not commercially significant.

It was common practice when these wells were drilled to carefully place several quarts of nitroglycerine in the hole adjacent to the productive sandstone. A "torpedo" containing a timing device or electronic detonator and explosive would be placed in the hole to detonate the nitroglycerine, which fractured the surrounding rock when it exploded. The fractures allowed oil to flow more easily to the well-bore, where it could be pumped out. This practice, known as "shooting a well," was inherently dangerous because nitroglycerine is a relatively unstable explosive. Despite careful handling and transport, unexpected explosions, injury, and occasional deaths were not uncommon among well shooters. This practice has largely been replaced by hydraulic fracturing; this much safer method uses a viscous fluid mixed with sand that is pumped into the hole under high pressure until it cracks and enters the adjacent rock. The fluid is pumped out, and the fractures are held open by the sand; the oil can then flow toward the well-bore.





